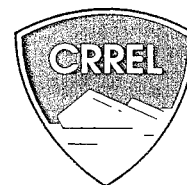


94-30

SPECIAL REPORT



# Layer Coefficients for NHDOT Pavement Materials

Vincent C. Janoo

September 1994



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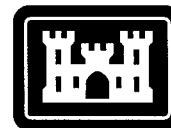
### ***Abstract***

In 1992, the New Hampshire Department of Transportation (NHDOT) experimented with the use of reclaimed asphalt concrete as a base course material, identified by NHDOT as reclaimed stabilized base (RSB). The RSB and a control test section were placed on Interstate 93 between exits 18 and 19. The RSB test section was designed to the same structural number (SN) as the control. To evaluate the structural capacity of these test sections, the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) conducted deflection tests using a Dynatest 8000 falling weight deflectometer (FWD). Preliminary analysis of the results by NHDOT personnel showed higher deflections in the reclaimed asphalt concrete test sections. The explanation was that the layer coefficient used for the RSB layer in the design was probably incorrect. A total of 10 test sections constituting the base course materials used by NHDOT were built near Bow, New Hampshire. CRREL evaluated and estimated the layer coefficients of the base course materials. The test program was developed to characterize the material in more than one way. Tests were conducted with the heavy weight deflectometer (HWD), dynamic cone penetrometer (DCP) and the Clegg hammer. In-situ California bearing ratio (CBR) tests were also conducted. The deflections from the HWD were used with the WESDEF back-calculation program to determine the layer moduli. The moduli were then used with the AASHTO Design Guide to calculate the layer coefficients. The layer coefficients were also determined with the method proposed by Rohde. The CBR values from the Clegg hammer, in-situ CBR and DCP tests were also used in the relationships in the HDM model to determine the layer coefficients.

For conversion of SI metric units to U.S./British customary units of measurement consult ASTM Standard E380-89a, *Standard Practice for Use of the International System of Units*, published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.

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# Special Report 94-30



**US Army Corps  
of Engineers**

Cold Regions Research &  
Engineering Laboratory

## Layer Coefficients for NHDOT Pavement Materials

Vincent C. Janoo

September 1994

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## **PREFACE**

This report was prepared by Dr. Vincent C. Janoo, Research Civil Engineer, Civil and Geotechnical Engineering Research Branch, Experimental Engineering Division, U.S. Army, Cold Regions Research and Engineering Laboratory. Funding was provided by the New Hampshire Department of Transportation (NHDOT) in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

Technical review of the manuscript of this report was provided by Alan Rawson, Alan Perkins, Glenn Roberts and Paul Mathews (NHDOT) and William Quinn and Robert Eaton (CRREL). Special thanks are given to Kristine Rezendes for managing the data and keeping track of the project; John Bayer, Christopher Berini, Richard Roberts, Brian Waehler and Pamela Chin for conducting the field tests; and also to our guest, Erik Simonsen from the Royal Institute of Technology, Sweden, for assisting in the testing program.

The contents of this report reflect the views of the author, who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration at the time of publication. This report does not constitute a standard specification, or regulation. The contents of this report are not to be used for advertising or promotional purposes. Citation of brand names does not constitute an official endorsement or approval of the use of such commercial products.

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# Layer Coefficients for NHDOT Pavement Materials

VINCENT C. JANOO

## INTRODUCTION

In 1992 the New Hampshire Department of Transportation (NHDOT) experimented with its use of reclaimed asphalt concrete as a base course material. NHDOT identifies asphalt concrete and crushed gravel base mixed in place as Item 306, reclaimed stabilized base (RSB). Falling weight deflectometer (FWD) tests were conducted on a section where 76 mm of asphalt concrete had been removed from the original pavement structure on Interstate 93 between exits 18 and 19. This is identified as the control section. Later, the remaining asphalt concrete layer was crushed and mixed in place with part of the existing base course. This is identified as an RSB section. It was assumed that the RSB test section had the same structural number (SN) as the control. Prior to placing the final 76 mm on the RSB section, FWD tests were again conducted.

The FWD tests were conducted by the U.S. Army Cold Regions Research and Engineering Laboratory (USACRREL) using a Dynatest 8000 falling weight deflectometer. Preliminary analysis of the results by NHDOT personnel showed higher deflections in the RSB section, suggesting a lower SN than the control. The explanation was that the layer coefficient used for the RSB layer in the design was probably incorrect.

NHDOT uses the *American Association of State Highway and Transportation Officials (AASHTO) Guide for Design of Pavement Structures*. This design procedure uses the SN concept developed from the AASHTO Road tests conducted in the late 1950s and early 1960s. The SN of a pavement structure is an index that describes the structural capacity of the pavement based on the expected traffic, subgrade and drainage conditions. The different pavement layers contribute to the overall bearing capacity, identified by the SN. The contribution is by layer of thickness, which is controlled by the material used in the layers. The stiffness of the layer is characterized by a layer coefficient ( $a_i$ ). Mathematically, the SN can be related to the thicknesses of the layers by the following equation:

$$SN = a_1 d_1 + m_1 a_2 d_2 + m_2 a_3 d_3$$

$$= \sum_{i=1}^n a_i d_i$$

where  $a_i$  = layer coefficient  
 $d_i$  = thickness of the layer  
 $m_i$  = drainage coefficient of the layer.

The layer coefficient is a multiplier for the thickness of the layer(s) required to carry the expected load. The stiffer the supporting layer, the higher the  $a_i$  will be. For example, from the AASHTO road tests, the layer coefficient of asphalt is 0.44; for crushed stone base course, it is 0.14; and for sandy gravel subbase, 0.11. Currently NHDOT uses the following layer coefficients as shown in Table 1.

Based on the results from the RSB test section, NHDOT decided to reevaluate the layer coefficients used in their design. A Cooperative Research and Development Agreement (CRDA) was established between CRREL and NHDOT to determine the layer coefficients of the reclaimed stabilized base and reevaluate the layer coefficients of the other commonly used base and subbase materials in the State of New Hampshire.

Test sections of different materials were built by NHDOT near Concord off Interstate 89 in 1993. USACRREL conducted FWD and other tests on these test sections. The aim was to use the deflections to back-calculate the layer modulus ( $E_i$ ). This  $E_i$  is then used with established relationships for determining the layer coefficients in the 1993 *AASHTO Guide for Design of Pavement Structures*. This report

Table 1. Layer coefficients used by NHDOT.

| Material                                 | Layer coefficients<br>( $a_i$ ) |
|--|---------------------------------|
| Hot bituminous base course               | 0.34                            |
| Hot bituminous binder and wearing course | 0.38                            |
| Crushed gravel base                      | 0.10                            |
| Gravel base                              | 0.07                            |
| Crushed stone                            | 0.14                            |
| Sand                                     | 0.05                            |
| Reclaimed stabilized base                | 0.17                            |

describes the tests conducted and analysis performed to determine the layer coefficients.

## DESCRIPTIONS

### Description of test site

NHDOT provided a test area near Bow, New Hampshire. The test area was located in an area used as a maintenance site by the contractors for a paving project on Interstate 89. This site was parallel to the interstate between exits 2 and 3 Southbound, approximately 3.2 km from the Concord town line.

Prior to the construction of the test sections, the subgrade was leveled and compacted to required NHDOT specifications. Since back-calculation methods were planned to determine the base course modulus, it was necessary to know if any bedrock was close to the surface. Data analysis problems have been encountered when rigid layers close to the surface are not taken into account. NHDOT performed a seismic refraction test and made some borings down to a depth of approximately 3.3 m. The results from the auger holes showed no bedrock to 3.3 m. The seismic refraction data showed no bedrock to a depth of 27 m.

Visual observation showed large boulders excavated at the site. It appears that the subgrade in the area was glacially deposited with suspended boulders below grade. Gradation analysis of the subgrade was performed by NHDOT personnel. The results from the gradation analysis are presented in Figure 1. The soil is classified as a silty sand (SM) using the Unified Soil Classification System because of the high amount passing the no. 200 sieve. With respect to AASHTO classification, the subgrade could be classified as an A2-5 soil.

### Description of test sections

A total of 10 test sections were built. The test sections were 30.5 m long  $\times$  3.7 m wide. The design thickness for all test sections was 200 mm. The location of the test sections is shown in Figure 2. The materials used in the test sections are shown in Table 2. The number in the parenthesis, next to the material, is the required gradation specification number of NHDOT. Detailed specifications of the material

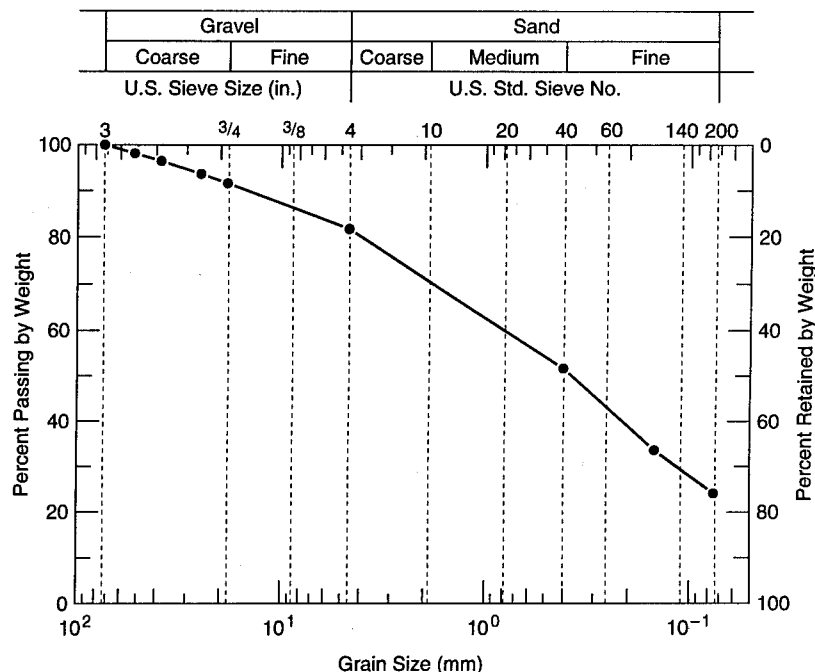


Figure 1. Gradation curve of subgrade soil.

can be found in the NHDOT specifications book.

For base course materials, the specifications call for hard durable particles of stone or gravel, resistant to deterioration when subjected to either freeze-thaw or wet-dry cycling. The fines can be either natural or processed sand. For crushed gravel, at least 50% of the material retained on the 25-mm sieve shall have a minimum of one fractured face.

RSB is a blend of pulverized asphalt concrete and crushed base course gravel. Because of the difficulty of meeting the gradation (306), an amendment was made to the gradation. The current requirement is 100% passing the 75-mm sieve. Four RSB test sections were constructed at the test site. According to NHDOT, the minimum 3% asphalt content specified has been difficult to achieve. To evaluate the effect of the asphalt content on the RSB, the percentages chosen for this research were 2%, 3% (two test sections), and 4%. One of the 3% asphalt content RSB test sections was compacted in two 100-mm layers. The reason for the 100-mm lift for the RSB test section was that NHDOT personnel had concerns that in thicker lifts, the bottom layers might have compaction values lower than in the upper layers. They believed that some form of

Table 2. Materials used in test sections.

|                                 |
|---------------------------------|
| Gravel (304.2)                  |
| Crushed gravel (304.3)          |
| Crushed stone—fine (304.4)      |
| Crushed stone—coarse (304.5)    |
| Reclaimed stabilized base (306) |
| Asphalt concrete                |
| Pavement millings               |



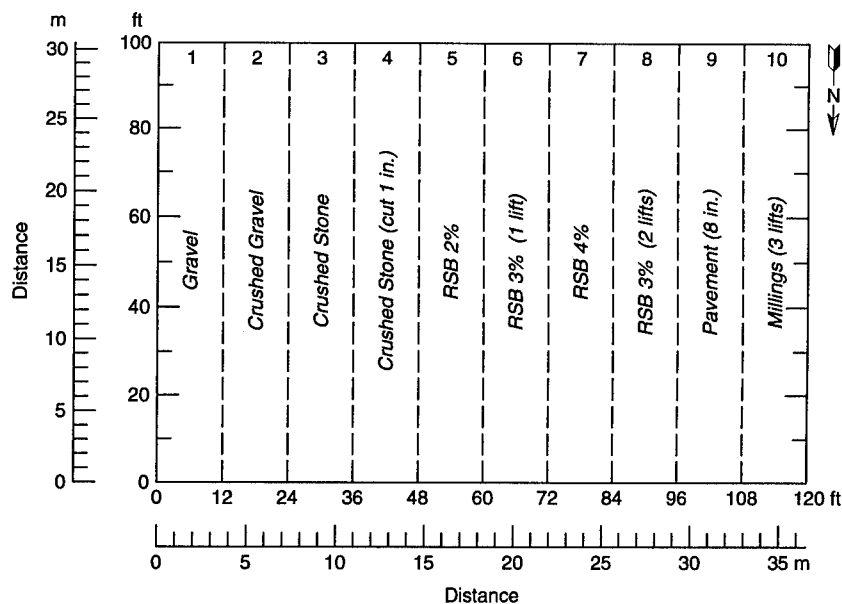


Figure 2. Materials used in test sections.

"bridging" might occur in the lower layers because of the cementitious nature of the material.

The pavement millings were placed in 3 lifts (75 mm, 75 mm, and 50 mm). The asphalt concrete pavement was placed in two 63-mm lifts of 31.5-mm base course, one 44-mm lift of 19-mm binder course, and one 25-mm lift of 12.5-mm wearing course.

Bag samples of the different materials were obtained during construction. CRREL personnel conducted gradation analysis of the test materials. The results of the gradation analysis are presented in Appendix A. Included in the figures are photographs of the test materials.

## TEST PROGRAM

The test program was developed to characterize the material in more than one way. Tests were conducted with the heavy weight deflectometer (HWD), dynamic cone penetrometer (DCP) and the Clegg hammer. The HWD is basically an FWD that applies a greater load: the maximum load applied by an FWD is 120 kN and by an HWD is more than 240 kN. In-situ California bearing ratio (CBR) tests were also conducted.

As mentioned above, the deflections from the FWD can be used with back-calculation techniques to determine the layer coefficients. Also, Rohde (1994) and Noureldin (1992) have developed methods for determining the SN of a pavement structure using the deflection data only. Back-calculation using layered elastic theory of layer moduli is not required by these methods. Rohde developed regression equations, based on a statistical study, between

one or two of the measured deflections with the SN of the pavement. Chastain et al. (1964) developed relationships between CBR and layer coefficients from their studies of the AASHTO Road Tests. CBR results can also be inferred from DCP tests. Webster (1992) and Kleyn and Savage (1982) developed relationships between the penetration rate of the DCP and CBR. The CBR values from the Clegg hammer, in-situ CBR and DCP tests will be used in the relationships in the HDM model (Watanatada et al. 1987) to determine the layer coefficients.

Prior to construction of the test sections (14-16 August 1993), the subgrade was tested with the HWD, Clegg hammer, DCP and in-situ CBR test. The FWD (or HWD) is now commonly used by many state DOTs to evaluate their pavement structure (Fig. 3). Basically, a HWD applies a known load on the surface of the pavement or subgrade. The pavement or subgrade deflects and the seven geophones, located at various distances from the center of the load, measure the surface deflection (Fig. 4).

Generally, the deflections are used with layered elastic theory to back-calculate the layer moduli of the pavement structure. Currently, there are many sophisticated back-calculation computer programs, such as the Corps of Engineers' WESDEF and the Strategic Highway Research Program's (SHRP) MODULUS for this purpose. Basically the programs iterate to a solution by varying the layer moduli. The solution is obtained when the error between the calculated and measured deflections are minimized. The program reports the layer moduli. For simple systems, such as a one-layer system (as in our case with the subgrade), the elastic modulus can also be

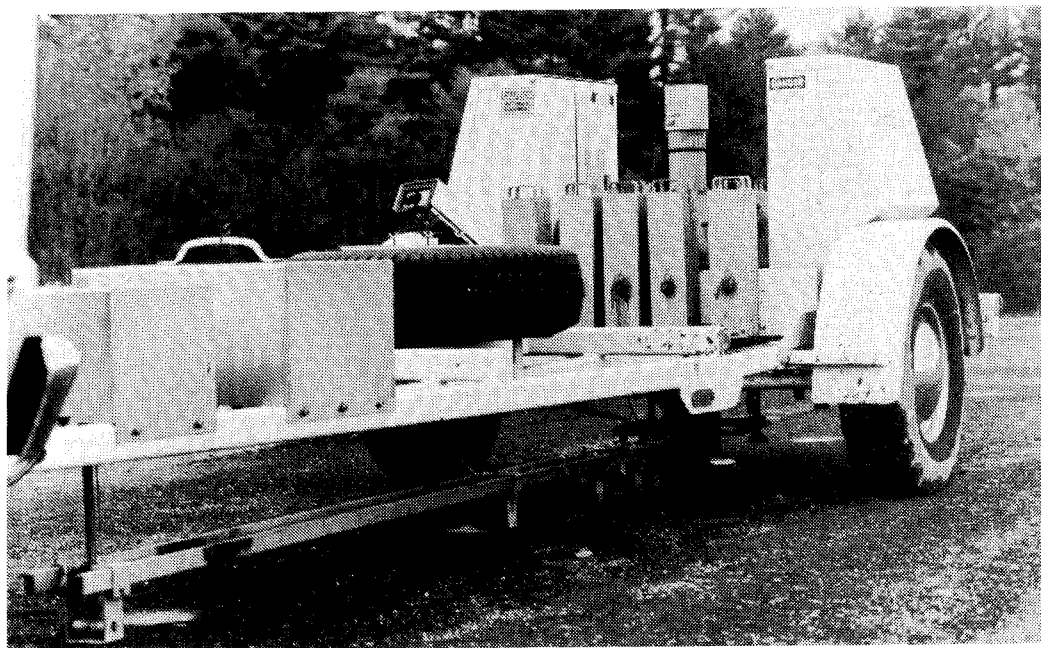


Figure 3. Heavy weight deflectometer (HWD).

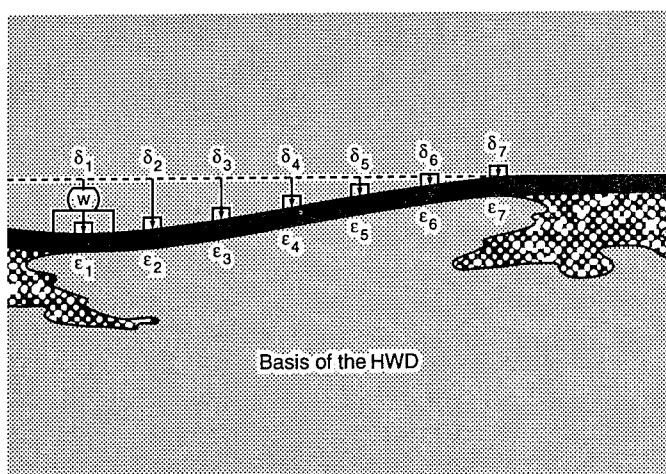


Figure 4. Basis of HWD testing.

back-calculated using the modified Boussinesq equation. With two layer systems we can use the two-layered Burmister model or use WESDEF to back-calculate the layer moduli. We used WESDEF to back-calculate the layer moduli of layers in the test sections. The back-calculated base course layer moduli were then used with relationships presented in the *AASHTO Guide for Design of Pavement Structures* to obtain the layer coefficients ( $a_i$ ).

The SHRP protocol for pavement evaluation was used in the HWD test program. The tests were conducted at four load levels. The loading sequence used on the subgrade and base course test sections is

as follows. Three seating loads are applied at the third load level and then each load level is applied four times to the surface. On the subgrade, the load levels used were approximately, 20, 33, 44 and 53 kN. Normally, the 300-mm loading plate is used. However, to minimize the stress on the subgrade surface, a larger plate (diam. = 450 mm) was used. The seven geophones for the subgrade testing were located 0, 305, 457, 610, 914, 1219 and 1524 mm from the center of the load. On the base test sections, load levels around 27, 38, 44 and 53 kN were used. The seven geophones for the base course testing were located 0, 200, 305, 457, 610, 914, and 1524 mm from the center of the load.

HWD measurements were conducted starting and ending 3.0 m from the ends of the test sections. In between, tests were conducted at 1.5-m intervals, for a total of 17 points (Fig. 5). The deflections were normalized to the standard 40 kN. The normalized results are presented in Appendix B.

Clegg hammer and DCP tests were conducted on the subgrade and on the completed test sections. The Clegg hammer is essentially a modified AASHTO compaction hammer fitted with a piezoelectric accelerometer (Fig. 6). It is used in Canada, Europe and Australia for compaction control of subgrade, subbase and base courses. A 4.5-kg hammer is raised to a height of 457 mm inside a guide tube and dropped. A hand-held meter measures the peak deceleration as the hammer hits the surface.

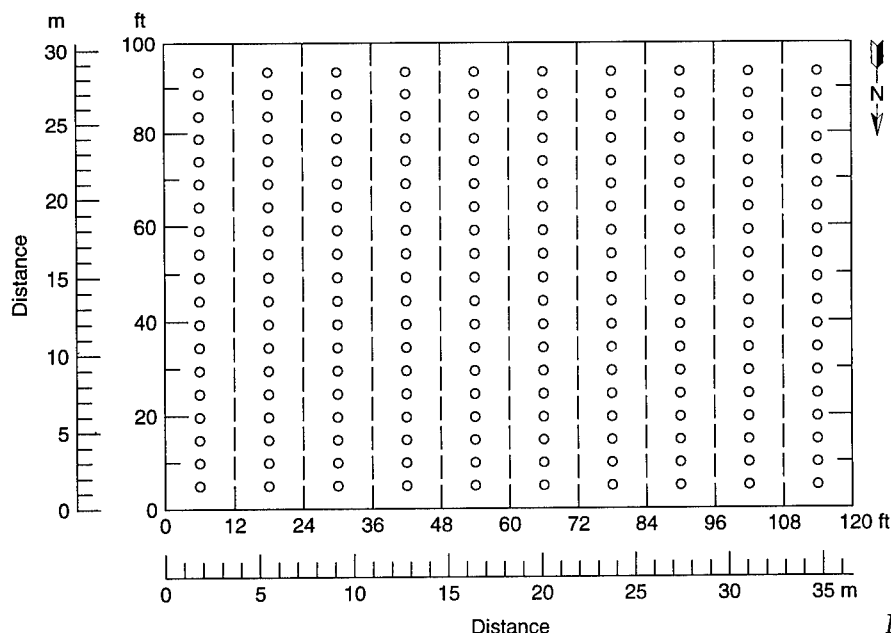


Figure 5. Location of FWD points.

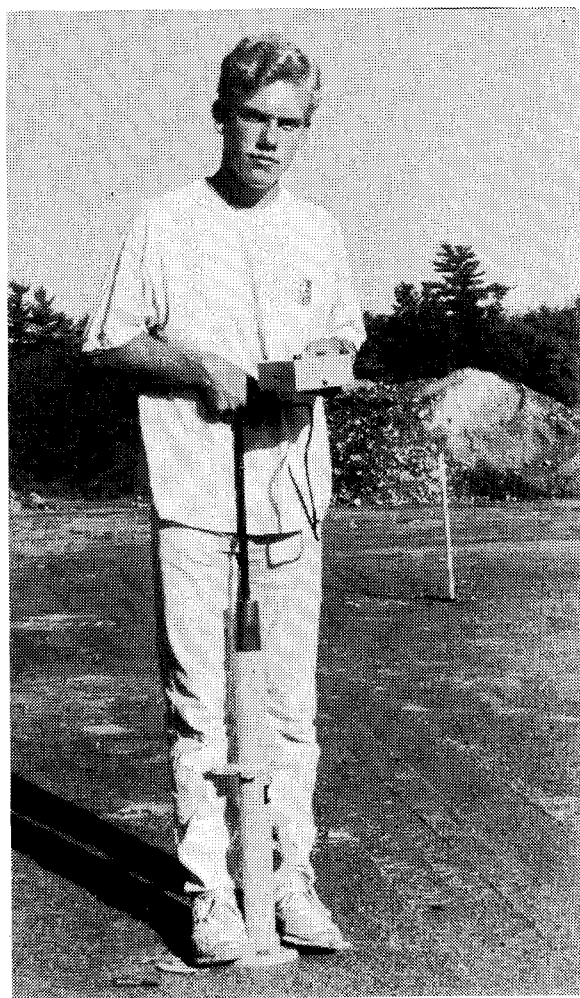


Figure 6. Clegg hammer.

The deceleration is presented as the Clegg impact value (CIV). A relationship between the CIV and CBR has been established:

$$CBR(\%) = 0.07 (CIV^2)$$

A similar relationship was found between the elastic modulus ( $E$ , in kPa) and CIV:

$$E = 70 (CIV^2)$$

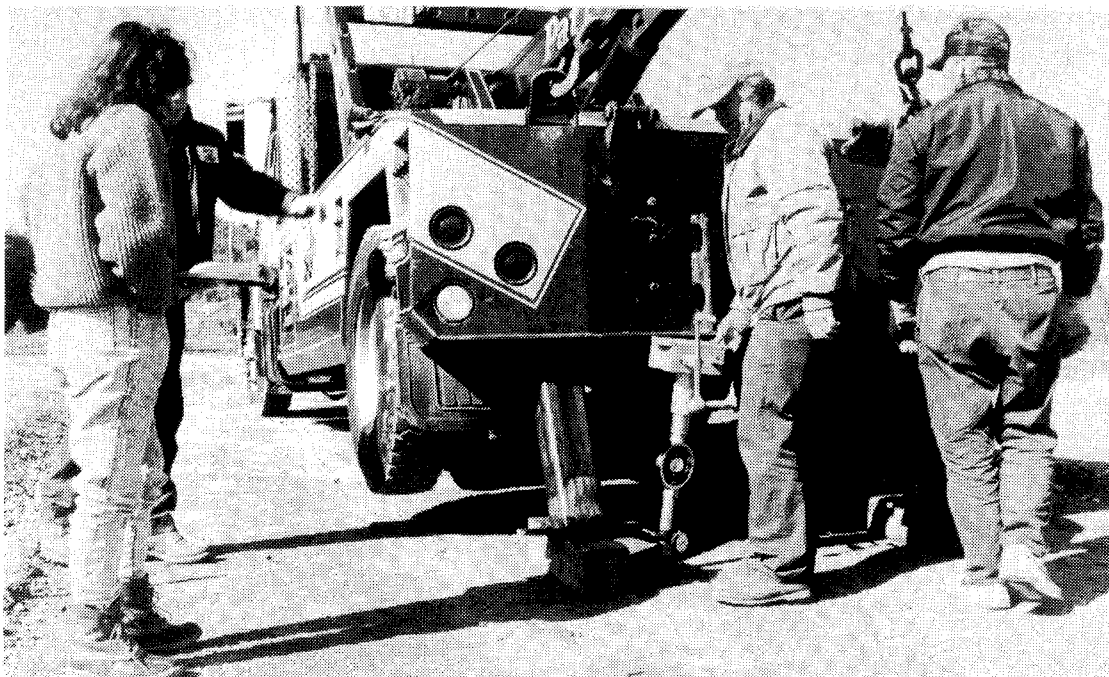
The DCP has also been used to characterize the bearing capacity of the supporting layers of a pavement structure. The DCP used in this test program is shown in Figure 7. The DCP consists of a 4.5-kg hammer. The hammer is raised to a height of 584 mm and dropped on the anvil. The force on the anvil drives the cone into the soil. Penetration measurements were made to a depth of approximately 305 mm. The number of blows required to drive the cone to a depth of 25 mm is noted.

The DCP Index, which is the amount of penetration per blow, is calculated by dividing the depth of penetration by the number of blows. Relationships between the DCP index and CBR have been developed by the Corps of Engineers (Webster et al. 1992).

To minimize the effect of site variability, the locations of the DCP and Clegg hammer tests were very close to the FWD test locations. In-situ CBR tests were conducted at 6, 15, and 24 m along the centerline from the beginning of the test section (Fig. 8). Surface elevations on top of the subgrade were taken at the HWD test points. After the test sections



*Figure 7. Dynamic Cone Penetrometer (DCP).*



*Figure 8. In situ California bearing ratio test.*

were built, the HWD points were transferred to the surface of the test sections. The HWD tests were repeated, in the same fashion as done with the subgrade. Similarly, in-situ CBR tests and surface elevations were done on top of the test sections. At the time HWD measurements were made, NHDOT personnel assisted in conducting near-surface density and moisture measurements of the subgrade.

## RESULTS/ANALYSIS OF SUBGRADE TESTING

The load deflection data were normalized to 40 kN, representing half an 80-kN axle load. Since no bedrock was indicated to a depth of 60 ft, the subgrade was idealized as a half space. The vertical deflection equations modified by Ahlvin and Ulery (Yoder and Witzcak 1975) were used to determine the subgrade modulus.

The vertical deflection ( $\Delta z$ ) is given by

$$\Delta z = \frac{p(1+\mu)}{E} \left[ \frac{z}{d} A + [(1-\mu)H] \right]$$

If Poisson's ratio ( $\mu$ ) = 0.5 and surface deflections are measured ( $z = 0$ ), then

$$\Delta z = \frac{1.5pa}{E} [0.5H]$$

If we use the deflection under the center plate, then  $H = 2.0$  and

$$\Delta z = \frac{1.5pa}{E}$$

or

$$E = \frac{1.5pa}{\Delta z}$$

where  $p$  = applied stress (kPa)  
 $a$  = plate radius (m)  
 $\Delta z$  = center surface deflection (m)  
 $E$  = elastic modulus (kPa).  
 $A, H$  = Ahlvin and Ulery functions

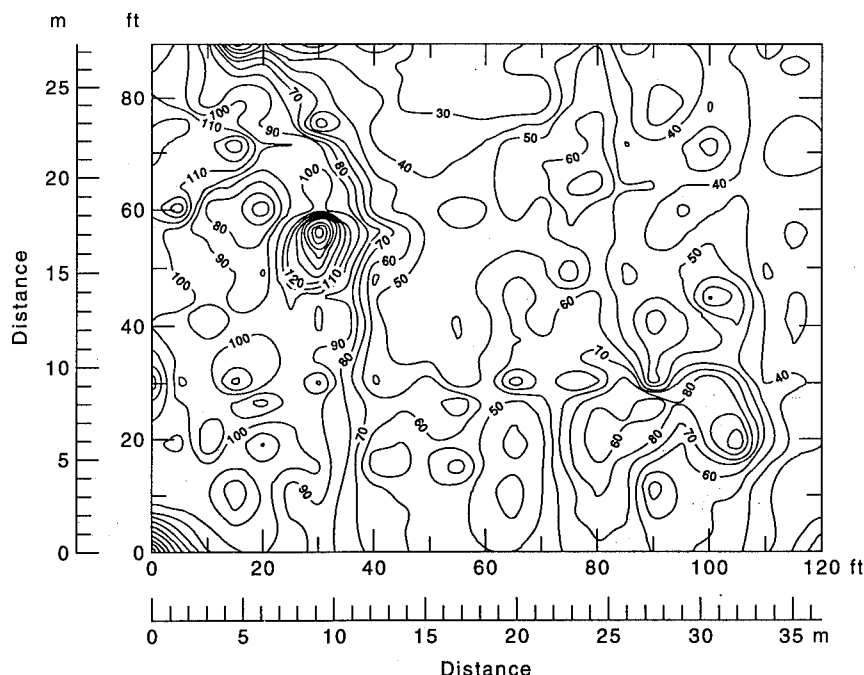


Figure 9. Clegg CBR profile of subgrade.

For a normalized load of  $F = 40$  kN and a plate radius of 225 mm then

$$p = \frac{F}{A} = \frac{F}{\pi a^2} = \frac{40}{\pi (0.225^2)} = 252 \text{ (kPa)}$$

and

$$E = \frac{1.5 \times 252 \times 0.225}{\Delta z} = \frac{85}{\Delta z} \text{ (kPa)}$$

The back-calculated subgrade modulus is presented in Appendix C. A comparison is made with the subgrade modulus calculated from the Clegg hammer data. It should be noted that the modulus from the Clegg hammer is from near the surface, whereas the modulus from the FWD is an average of a larger volume of soil. The data show that the modulus from the Clegg hammer in most cases is close to that obtained from the FWD. The modulus also shows that the area close to the interstate, in the area of the test sections 1 and 2, is much stiffer than the other areas. This is further substantiated by the CBR data from the Clegg hammer (Fig. 9) and the near-surface density measurements (Fig. 10). The near-surface gravimetric moisture content at the site ranges between 5 to 10% (Fig. 11). The wetter areas were close to the area where the test sections 9 and 10 were to be built. It was also observed that when it rained, there was no standing water in the area indicating a soil of high permeability.

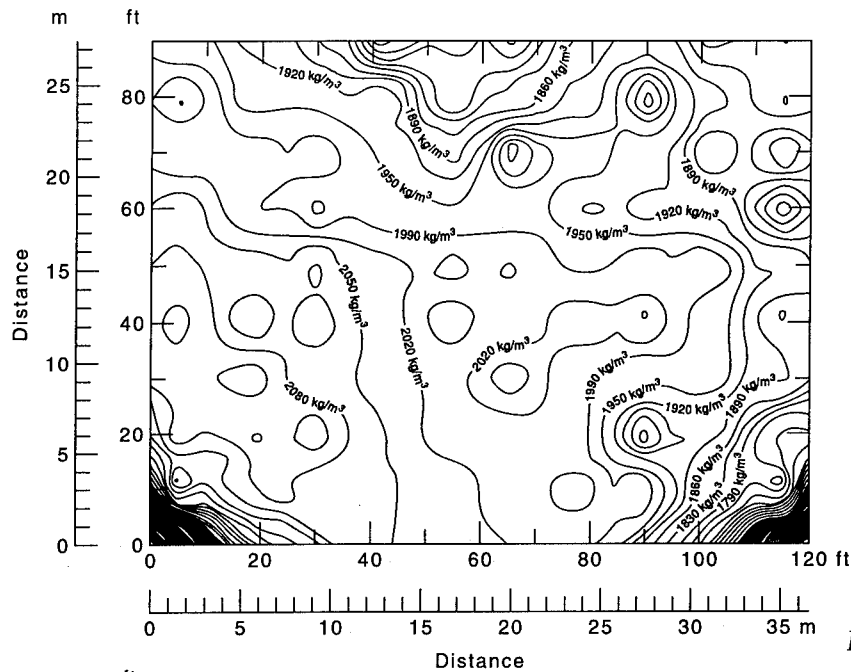


Figure 10. Density profile of subgrade.

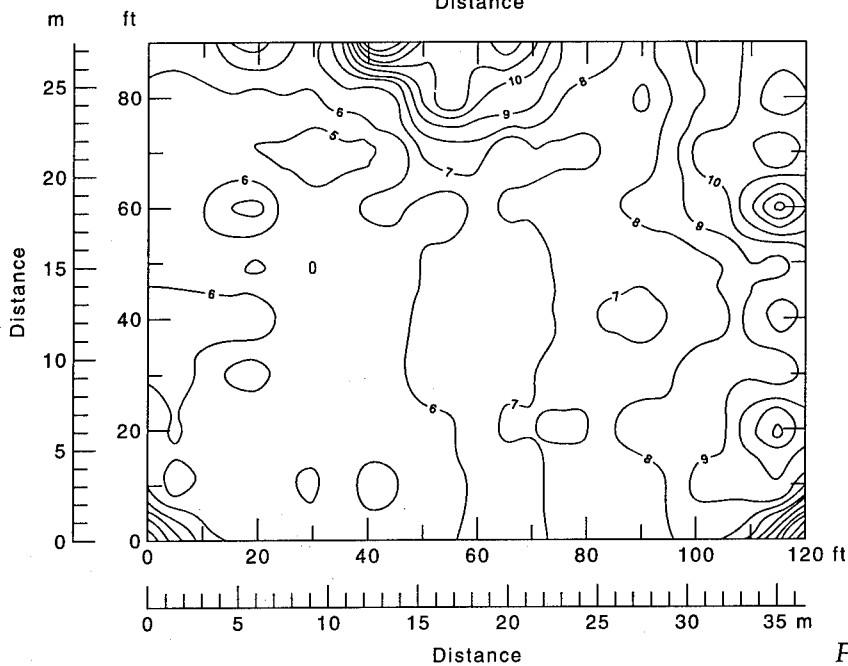


Figure 11. Moisture profile of subgrade.

## BASE COURSE TESTING

The base course layers were constructed in mid-September. During the construction, CRREL personnel installed thermocouples on top of the subgrade. These installations were made so that temperature measurements could be made in future studies to determine the seasonal effects on the stiffness of the different base courses. Bag samples of the materials were also collected at that time. CRREL returned to the test area to conduct FWD tests in early October 1993.

Besides the FWD tests, Clegg hammer, DCP, level surveys, and in-situ CBR were conducted. The level surveys were used with those from the subgrade to get the thickness of the test sections. The thicknesses based on our level surveys across the test sections are given in Table 3. These thicknesses and linear elastic theory were used in the Corps of Engineers WESDEF program to back-calculate the layer moduli. These thicknesses were also used in Rohde's method for determining the SN of the various base course layers.

Table 3. Base course layer thicknesses.

| Location ↓<br>Test section → | Thickness of base course (mm) |     |     |     |     |     |     |     |     |     |
|------------------------------|-------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|                              | 1                             | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
| +10                          | 180                           | 216 | 216 | 234 | 231 | 224 | 213 | 216 | 172 | 213 |
| +15                          | 193                           | 231 | 244 | 241 | 234 | 231 | 224 | 203 | 178 | 203 |
| +20                          | 172                           | 231 | 254 | 246 | 239 | 229 | 213 | 201 | 183 | 208 |
| +25                          | 185                           | 229 | 249 | 246 | 234 | 216 | 211 | 211 | 185 | 208 |
| +30                          | 208                           | 239 | 262 | 249 | 224 | 213 | 216 | 216 | 183 | 203 |
| +35                          | 226                           | 241 | 264 | 257 | 226 | 203 | 224 | 218 | 185 | 201 |
| +40                          | 231                           | 244 | 259 | 241 | 218 | 196 | 226 | 234 | 185 | 201 |
| +45                          | 224                           | 241 | 257 | 239 | 229 | 193 | 229 | 226 | 188 | 196 |
| +50                          | 224                           | 246 | 239 | 241 | 234 | 198 | 224 | 226 | 193 | 203 |
| +55                          | 234                           | 249 | 241 | 226 | 226 | 201 | 226 | 226 | 203 | 208 |
| +60                          | 226                           | 259 | 229 | 239 | 234 | 201 | 224 | 211 | 211 | 211 |
| +65                          | 231                           | 262 | 218 | 224 | 239 | 193 | 218 | 203 | 216 | 211 |
| +70                          | 226                           | 249 | 216 | 224 | 246 | 213 | 216 | 201 | 231 | 218 |
| +75                          | 218                           | 249 | 208 | 224 | 246 | 218 | 213 | 196 | 229 | 216 |
| +80                          | 224                           | 249 | 213 | 218 | 254 | 224 | 211 | 185 | 226 | 231 |
| +85                          | 229                           | 239 | 211 | 211 | 246 | 218 | 201 | 168 | 229 | 239 |
| +90                          | 224                           | 229 | 224 | 211 | 229 | 211 | 198 | 152 | 231 | 244 |

## DETERMINATION OF LAYER COEFFICIENTS ( $a_i$ )

### Back-calculation of layer moduli

Initially, the pavement structure was modeled as a two-layer system (Fig. 12a). From past experience with WESDEF, it was found that a rigid layer placed 6 m below the surface produced a better fit between the calculated and the measured deflection basin. Based on the seismic study conducted by NHDOT personnel, no bedrock (rigid layer) was found to a depth of 18 m. In our analysis, we placed a rigid layer separately at 6 and 18 m. The solution did not show much difference. For the two-layer system, it was found that the error between the calculated and measured deflections were extremely large. The pavement structure was remodeled as a three layer system (Fig. 12b). The subgrade was subdivided into two layers. The division was made at 305, 774, 914, 1219 and 1524 mm below the base course layer. The back-calculated base course modulus with the lowest error between the calculated and the measured deflection basin was used in the calculation  $a_i$ . The error was reduced significantly when the pavement structure was modeled as a three- instead of a two-layer system.

Prior to conducting the back-calculation of the base course modulus, we used the deflection basin area to locate points where

the basin area is within one standard deviation from the mean (Fig. 13-22). The basin area was used to locate areas of similar performance. The mean modulus of the different base courses is presented in Table 4. Note in Table 4, the AC modulus is not presented. This was because the modulus was higher than 3500 MPa. The AASHTO Design Guide relationship between AC modulus and  $a_i$  only goes up to 3500 MPa. The higher values result from the pavement being tested when it was cold.

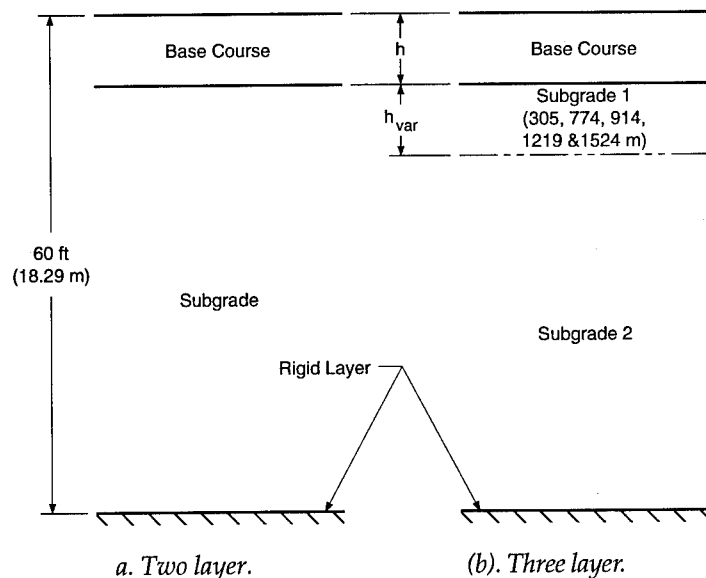


Figure 12. Representation of test sections in WESDEF.

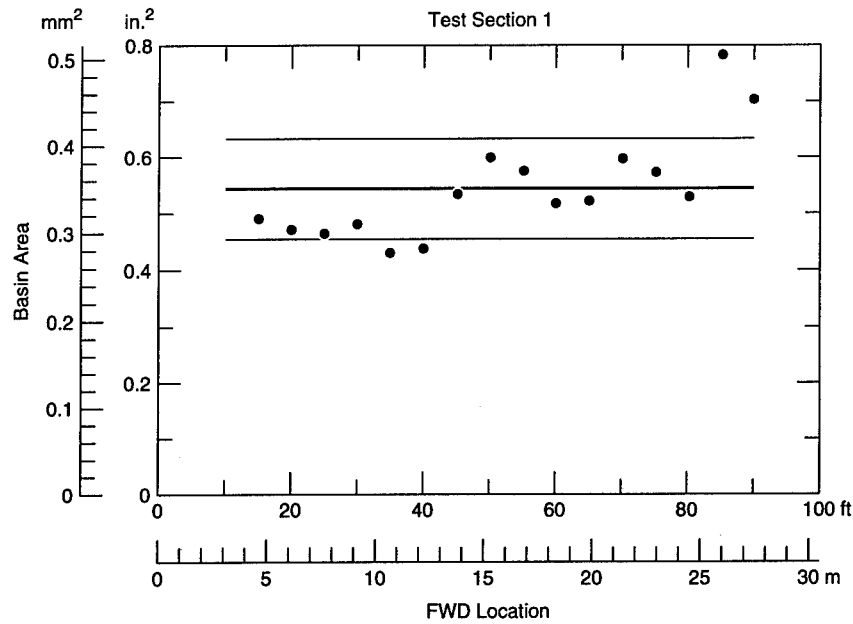


Figure 13. Deflection basin area for gravel.

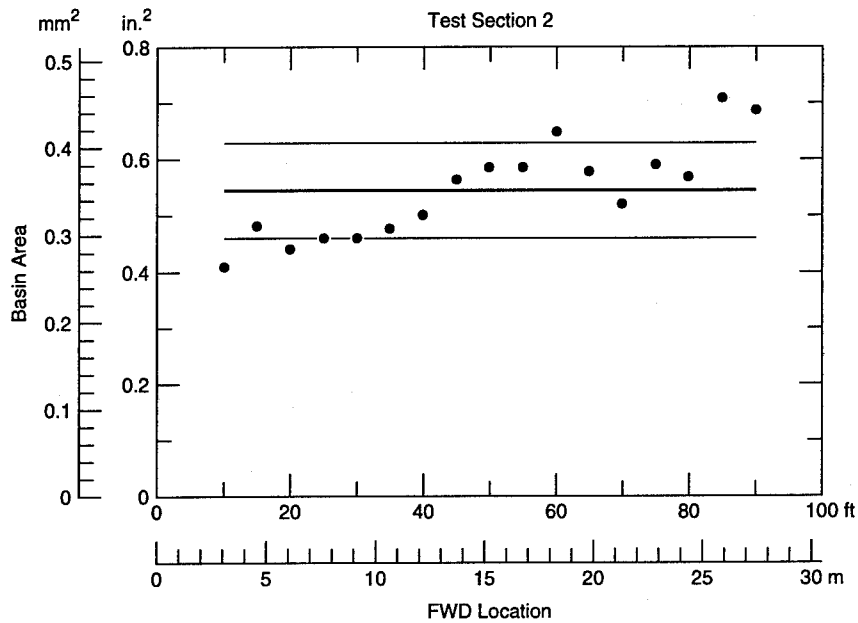


Figure 14. Deflection basin area for crushed gravel.

Table 4. Mean modulus and layer coefficient of base course materials.

| Material                               | $E_i$<br>(MPa) | $a_i$ |
|--|----------------|-------|
| Gravel                                 | 211            | 0.12  |
| Crushed stone (fine)                   | 168            | 0.16  |
| Crushed stone (coarse)                 | 231            | 0.19  |
| Reclaimed stabilized base (2%)         | 267            | 0.17  |
| Reclaimed stabilized base (3%)         | 262            | 0.16  |
| Reclaimed stabilized base (4%)         | 331            | 0.19  |
| Reclaimed stabilized base (3%—2 lifts) | 256            | 0.16  |
| Asphalt concrete                       | —              | —     |
| Pavement milling                       | 334            | 0.17  |

For the gravel, crushed gravel, RSB and pavement millings, the following equation from the 1993 AASHTO Design Guide was used:

$$a_2 = 0.249 (\log_{10} E) - 0.977.$$

For the crushed stone, the following equation from the 1993 AASHTO Design Guide was used:

$$a_3 = 0.227 (\log_{10} E) - 0.839.$$

The following  $a_i$  values were calculated from the back-calculated base course modulus. These results are also presented in Table 4.



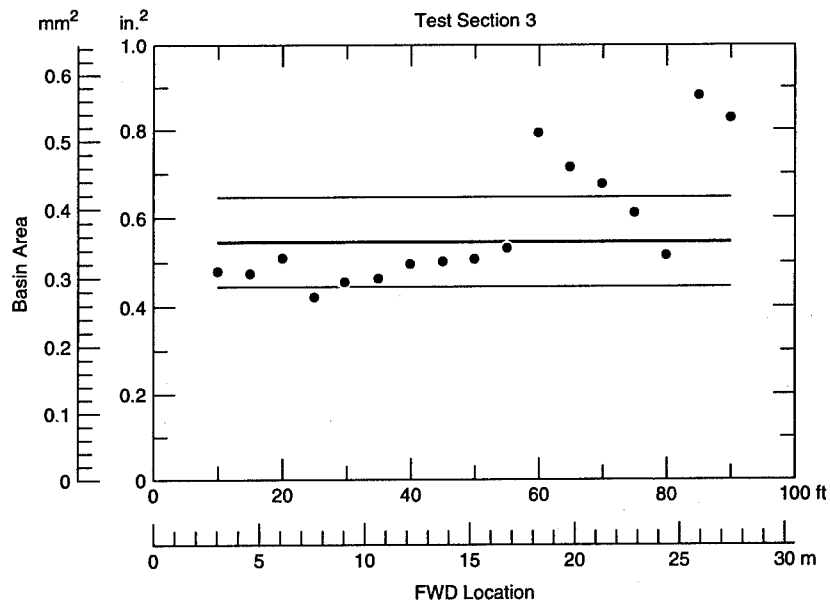


Figure 15. Deflection basin area for fine crushed stone.

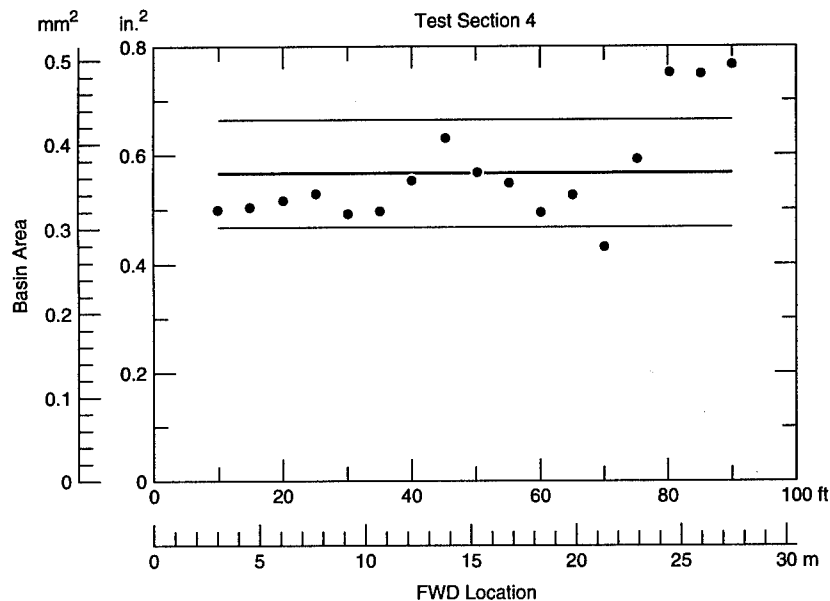


Figure 16. Deflection basin area for coarse crushed stone.

#### Determination of layer coefficients using FWD data

Rohde (1994) developed a method for determining the SN of a pavement structure using the FWD measurements. The SN equation used is the one modified by TRL in 1975 and used in the World Bank Highway Design and Maintenance pavement performance model (HDM-111 model). The modified structural number (SNC) is defined as

$$SNC = 0.0394 \sum_{i=1}^n a_{i,h_i} + SNSG$$

where SNSG is that portion of the structural number contributed by the subgrade. The following relationship for SNSG in terms of CBR has been used:

$$SNSG = 3.51 \log_{10} CBR - 0.85 (\log_{10} CBR)^2 - 1.43$$

where CBR = the in-situ California bearing ratio of the subgrade (%).

Based on Irwin's (1983), "two-thirds rule" of stress distribution under a pavement structure,

Rohde assumed that the deflection ( $D_{1.5h}$ ) measured at a distance on the surface equal to 1.5 times the structural section thickness ( $h$ ) is due to the subgrade only. He then developed the Structural Index of the Pavement (SIP). SIP is associated with the deflection above the subgrade only:

$$SIP = D_0 - D_{1.5h}.$$

The hypothesis is that the SIP should be strongly correlated with the stiffness of the pavement structure and thus to SN. Based on regression analysis, Rohde developed a relationship between SN and SIP:

$$SIP = k_1 SIP^{k_2} h^{k_3}.$$

The following values, 0.1165, -0.3248 and 0.8241 were used for  $k_1$ ,  $k_2$  and  $k_3$  for all the base courses with the exception of the asphalt concrete layer. For the AC layer, 0.4728, -0.4810 and 0.7581 were used as recommended by Rohde, respectively. For a two-layer system, the layer coefficient was calculated using

$$a_i = \frac{SNC - SNSG}{0.0394 * h}.$$

Rohde (1994) used the deflection data to determine the subgrade modulus ( $E_{sg}$ ). He developed

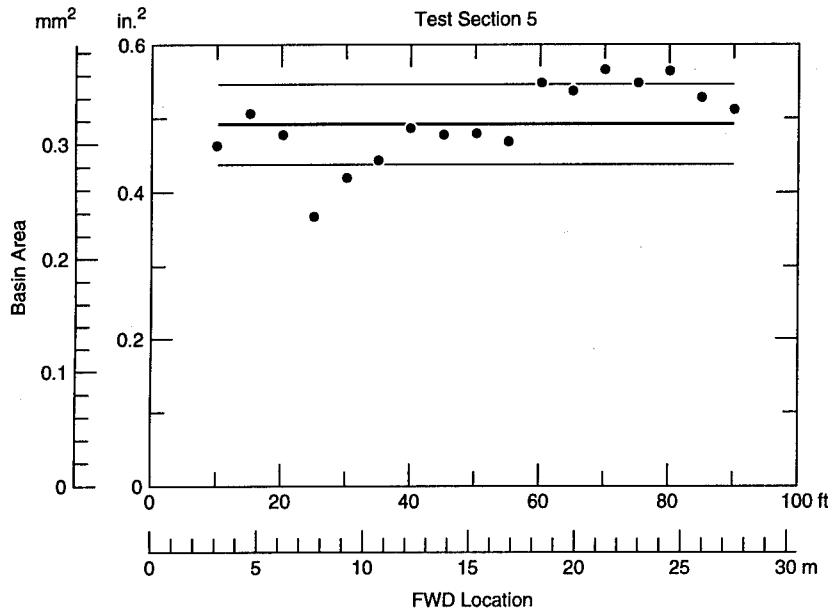


Figure 17. Deflection basin area for 2% RSB.

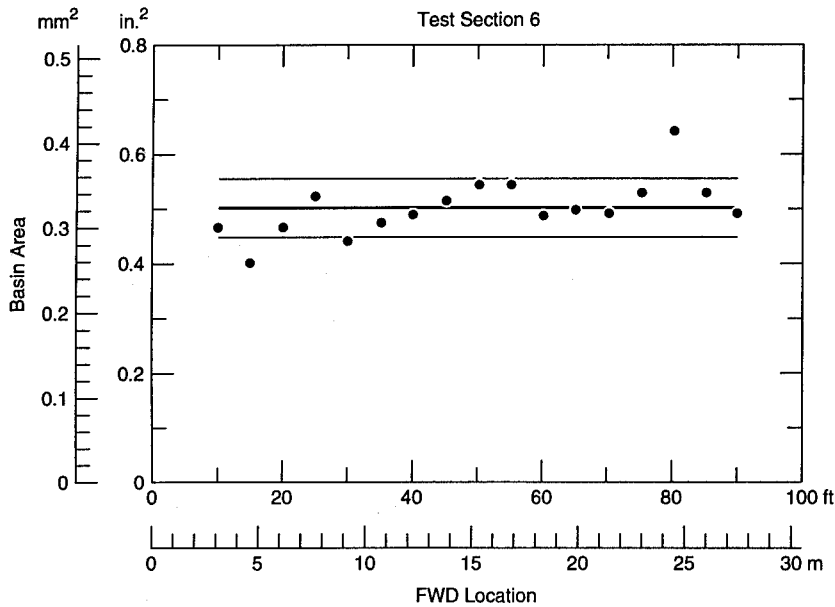


Figure 18. Deflection basin area for 3% RSB.

another index called the structural index of subgrade (SIS):

$$SIS = D_{1.5h} - D_s$$

where  $D_s$  is the deflection measured at a distance of 30 inches from the center plate. The subgrade modulus is

$$E_{sg} = 10^{k_4} SIS^{k_5} h^{k_6}$$

The following recommended values of 23138, -1,236 and -1.903 (Rohde 1994) were used for  $k_4$ ,  $k_5$ , and  $k_6$ . The CBR (%) of the subgrade was back-calculated from

$$E_{sg} = [1500 \times CBR^{0.73}] / 6.9, \text{ (kPa)}.$$

The mean  $a_i$  are presented in Table 5. The results are compared with that obtained from back-calculation.

The subgrade moduli obtained from the modified Boussinesq equation were also used in place of  $E_{sg}$  and the layer coefficients back-calculated. There were no significant differences between the two of them.

#### Determination of layer coefficients using CBR results

Field CBR data were obtained from the Clegg hammer and in-situ CBR testing (App. D). Also data from the DCP can be converted to CBR. The DCP data are converted to penetration per blow rate. The Corps of Engineers use the following relationship to convert the DCP rate to CBR:

$$CBR(\%) = \frac{292}{DCP^{1.12}}$$

where DCP = millimeters/blow.

Table 5. Layer coefficients for base course using Rohde's method.

| Material                               | Rohde (1994) | Back-calculation |
|--|--------------|------------------|
| Gravel                                 | 0.12         | 0.10             |
| Crushed gravel                         | 0.13         | 0.12             |
| Crushed stone (fine)                   | 0.13         | 0.16             |
| Crushed stone (coarse)                 | 0.14         | 0.19             |
| Reclaimed stabilized base (2%)         | 0.14         | 0.17             |
| Reclaimed stabilized base (3%)         | 0.14         | 0.16             |
| Reclaimed stabilized base (4%)         | 0.15         | 0.19             |
| Reclaimed stabilized base (3%—2 lifts) | 0.14         | 0.16             |
| Asphalt concrete                       | 0.37         | —                |
| Pavement milling                       | 0.15         | 0.17             |

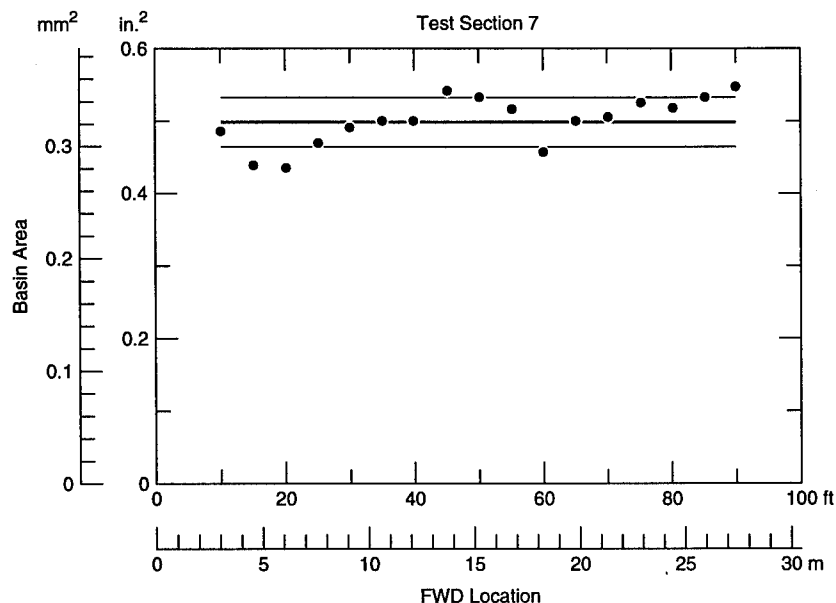


Figure 19. Deflection basin area for 4% RSB.

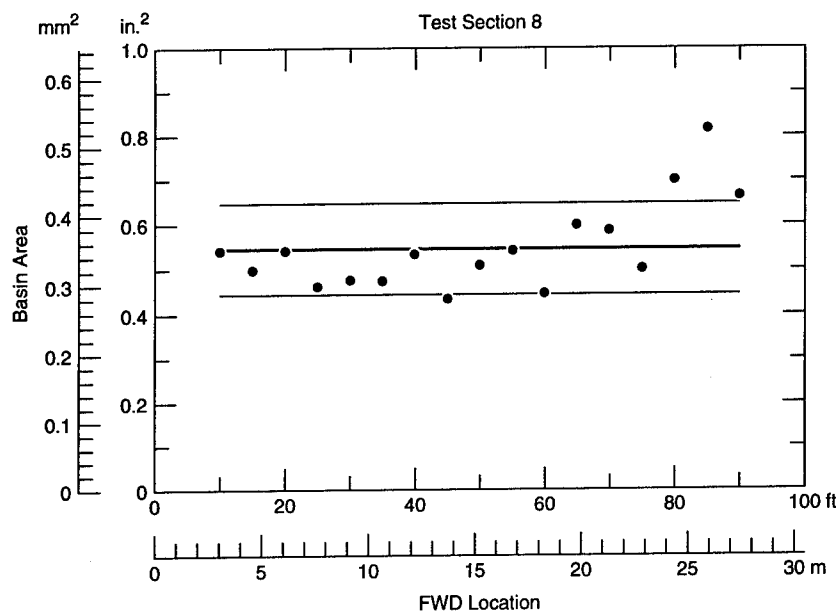


Figure 20. Deflection basin area for 3% RSB—two lifts.

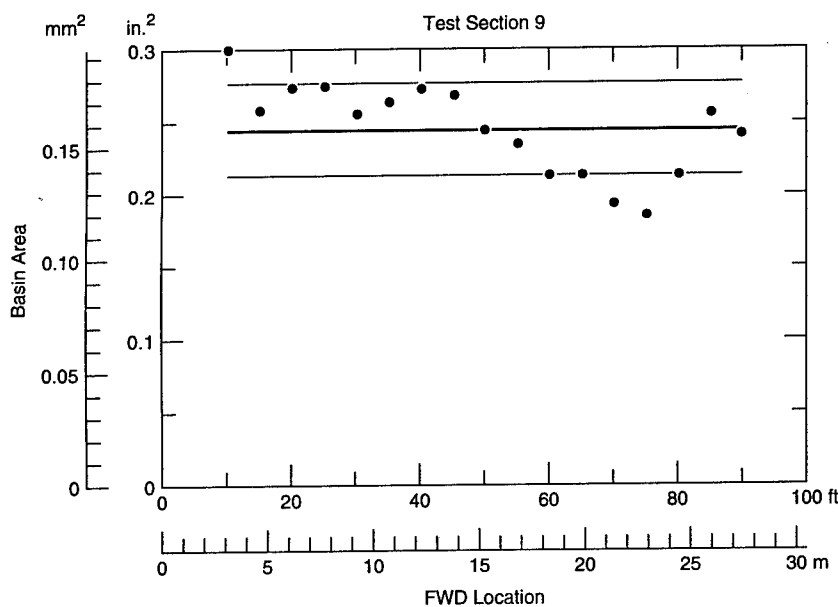


Figure 21. Deflection basin area for asphalt concrete.

Table 6. Back-calculated  $a_i$  from in-situ tests.

| Material                               | Clegg hammer | In situ | DCP  |
|--|--------------|---------|------|
| Gravel                                 | 0.07         | 0.02    | 0.04 |
| Crushed gravel                         | —            | 0.07    | 0.07 |
| Crushed stone (fine)                   | 0.10         | 0.05    | —    |
| Crushed stone (coarse)                 | 0.13         | 0.08    | —    |
| Reclaimed stabilized base (2%)         | *            | 0.06    | 0.11 |
| Reclaimed stabilized base (3%)         | 0.15         | 0.10    | 0.13 |
| Reclaimed stabilized base (4%)         | *            | 0.08    | 0.13 |
| Reclaimed stabilized base (3%—2 lifts) | 0.14         | 0.09    | 0.13 |
| Asphalt concrete                       | —            | —       | —    |
| Pavement milling                       | —            | 0.07    | 0.14 |

\* unreasonable values.

In the World Bank HDM-111 pavement performance model, there is a relationship between CBR and  $a_i$ ,

$$a_i = (29.14 \times \text{CBR} - 0.1977 \text{ CBR}^2 + 0.00045 \text{ CBR}^3) 10^{-4}.$$

The results from the calculations are presented in Table 6.

The in-situ test results in Table 6 are low when compared with either the Clegg hammer or DCP test results. This is probably due to the test method itself. The test involves measuring the

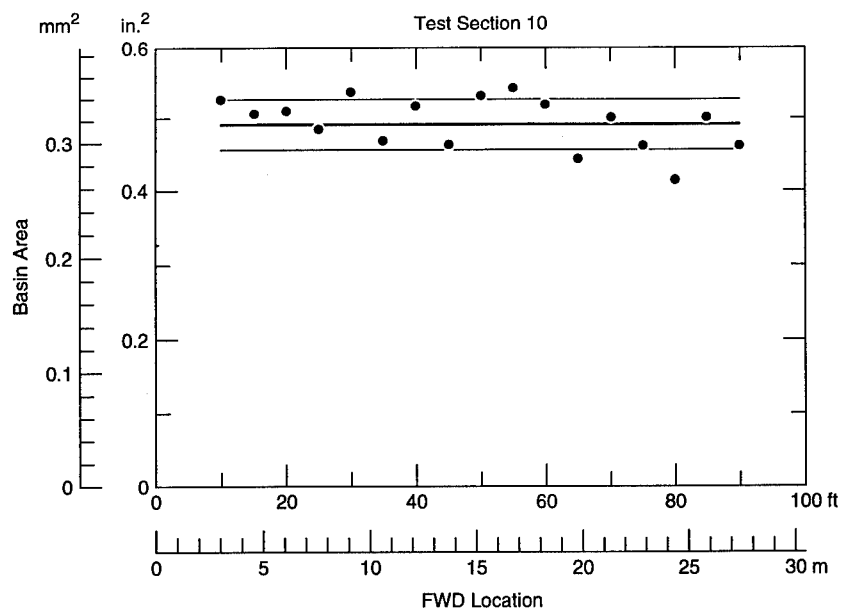


Figure 22. Deflection basin area for asphalt pavement millings.

Table 7. Summary of layer coefficients for New Hampshire base courses.

| Material                                | #200 (%)<br>In sand | #200 (%)<br>In total | NHDOT     | Back-calculation | Rohde | Clegg hammer | DCP  |
|---|---------------------|----------------------|-----------|------------------|-------|--------------|------|
| Gravel                                  | 4.5                 | —                    | 0.07      | 0.10             | 0.12  | 0.07         | 0.04 |
| Crushed gravel (87% fracture)           | 6.9                 | —                    | 0.10      | 0.12             | 0.13  | —            | 0.07 |
| Crushed stone (fine)                    | 10.8                | 3.8                  | 0.14      | 0.16             | 0.13  | 0.10         | —    |
| Crushed stone (coarse)                  | 15.8                | 4.1                  | —         | 0.19             | 0.14  | 0.13         | —    |
| Reclaimed stabilized base (2%)          | —                   | 5.7                  | 0.17      | 0.17             | 0.14  | *            | 0.11 |
| Reclaimed stabilized base (3%)          | —                   | 5.4                  | 0.17      | 0.16             | 0.14  | 0.15         | 0.13 |
| Reclaimed stabilized base (4%)          | —                   | 6.5                  | 0.17      | 0.19             | 0.15  | *            | 0.13 |
| Reclaimed stabilized base (3% —2 lifts) | —                   | 5.4                  | 0.17      | 0.16             | 0.14  | 0.14         | 0.13 |
| Asphalt concrete                        | —                   | —                    | 0.34–0.38 | —                | 0.37  | —            | —    |
| Pavement milling                        | —                   | 5.9                  | —         | 0.17             | 0.15  | —            | 0.14 |

\* unreasonable values.

amount of load required in maintaining a certain rate of needle penetration into the base course. The location of the needle in the test section will affect the test. The results from the test may reflect the strength of the fines in the test sections.

## SUMMARY OF RESULTS

The layer coefficients, calculated in several ways, are listed in Table 7 with the exception of the in-situ CBR tests. Except for the gravel and crushed gravel, the back-calculated layer coefficients from WESDEF are higher than the others. It was noted that the error between values measured with the FWD and predicted deflections were approximately 20%. This will produce some errors in the final base course

modulus. The back-calculated values using the FWD deflections (Rohde's method) appear to be close to those obtained from the Clegg and DCP data for the reclaimed stabilized base.

## RECOMMENDATIONS

When the I-93 RSB test sections were built in 1992, the layer coefficient used for the RSB layer was 0.17. These pavements were found to deflect more than the existing pavement. Based on this observation and the results of this research, the values listed in Table 8 are the suggested layer coefficients for New Hampshire pavement materials.

The suggested values were based on the following decisions:

**Table 8. Suggested layer coefficients for New Hampshire pavement materials.**

| Material                               | Suggested<br>$a_i$ |
|--|--------------------|
| Gravel                                 | 0.10               |
| Crushed gravel                         | 0.12               |
| Crushed stone (fine)                   | 0.13               |
| Crushed stone (coarse)                 | 0.14               |
| Reclaimed stabilized base (2%)         | 0.14               |
| Reclaimed stabilized base (3%)         | 0.14               |
| Reclaimed stabilized base (4%)         | 0.15               |
| Reclaimed stabilized base (3%-2 lifts) | 0.14               |
| Asphalt concrete                       | 0.37               |
| Pavement milling                       | 0.15               |

1. The layer coefficients obtained from the different methods were compared with the current NHDOT values. The Rohde values for the asphalt concrete were similar to the one used by the NHDOT. This gave confidence to the other layer coefficients obtained from the Rohde's method.

2. At this time, the layer coefficients obtained from the back-calculation procedure are questionable for two reasons. One, it was not possible to minimize the error between the calculated and measured deflections to below 10%, an acceptable COE standard. Second, the RSB back-calculated layer coefficients values were close to that used by NHDOT in the I-93 test section and the pavement deflections were high compared to the existing pavement. The expected deflections were supposed to be similar to the control test sections. However, the layer coefficient of the gravel from the back-calculation method was lower than that from Rohde's method. To be conservative, the lower value was chosen. For the crushed gravel the layer coefficients are similar from either method. Again the lower value was chosen. More FWD testing of existing roadway pavements is needed to develop confidence in the back-calculated values.

3. The layer coefficients from the Clegg hammer and the DCP are close to those obtained from the Rohde's method. This gives more confidence to the values suggested.

The structural performance between the one- and two-lift 3% RSB test sections could not be distinguished. It is recommended that cores be taken to determine if any segregation or bridging occurs during placement of thick RSB layers. Preliminary results from Quebec Ministry of Transportation indicate that the amount of reclaimed asphalt that can be used with the crushed gravel base must be limited to 30% by weight. When larger quantities are used,

the strength of the layer appears to decrease. More studies in this area need to be conducted.

The layer coefficients presented here were determined for one subgrade modulus. The AASHTO design procedure uses a weighted subgrade modulus to reflect the seasonal effects on the subgrade. The layer coefficients from a weighted subgrade modulus may be lower. It is recommended that tests be conducted over one year to characterize the seasonal material performance.

Finally, if the suggested layer coefficients are used, a follow-up study should be conducted to determine the seasonal structural performance of the pavement structure. Test sections using the old and new layer coefficients need to be constructed and their structural performance monitored to validate these values. Additional testing will be needed to develop confidence in the back-calculated layer coefficients.

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# APPENDIX A: GRAIN SIZE DISTRIBUTIONS OF TEST SECTION MATERIALS.

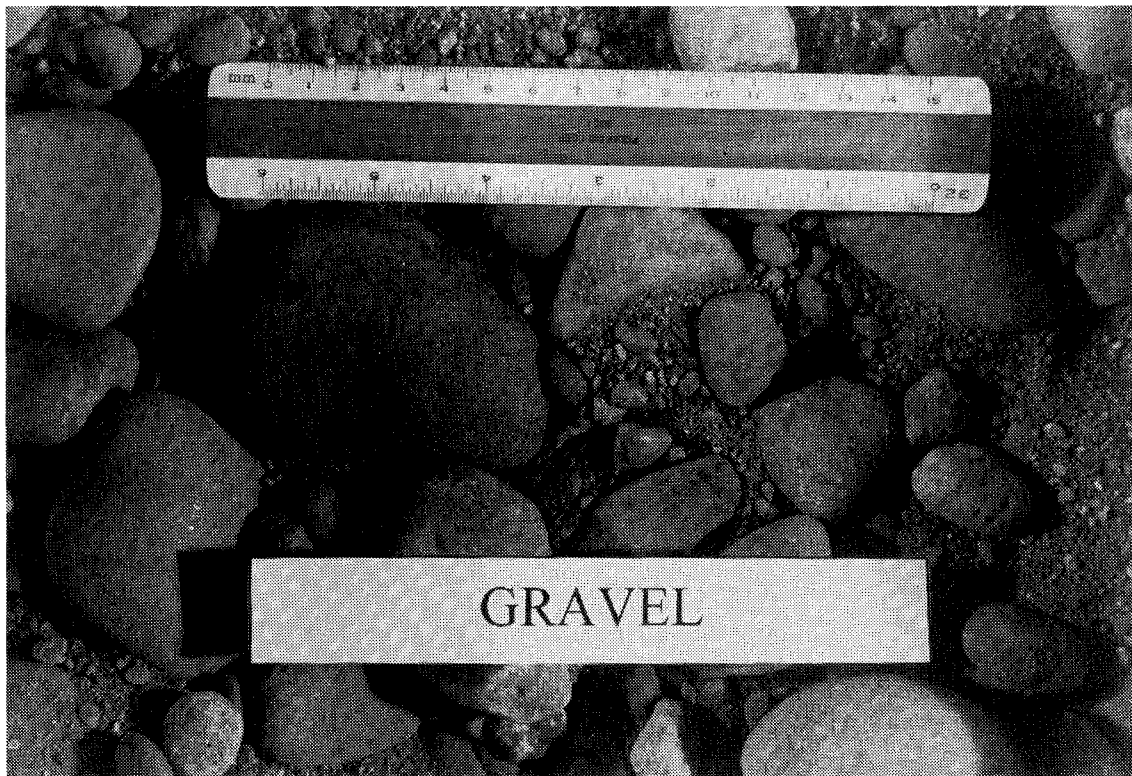
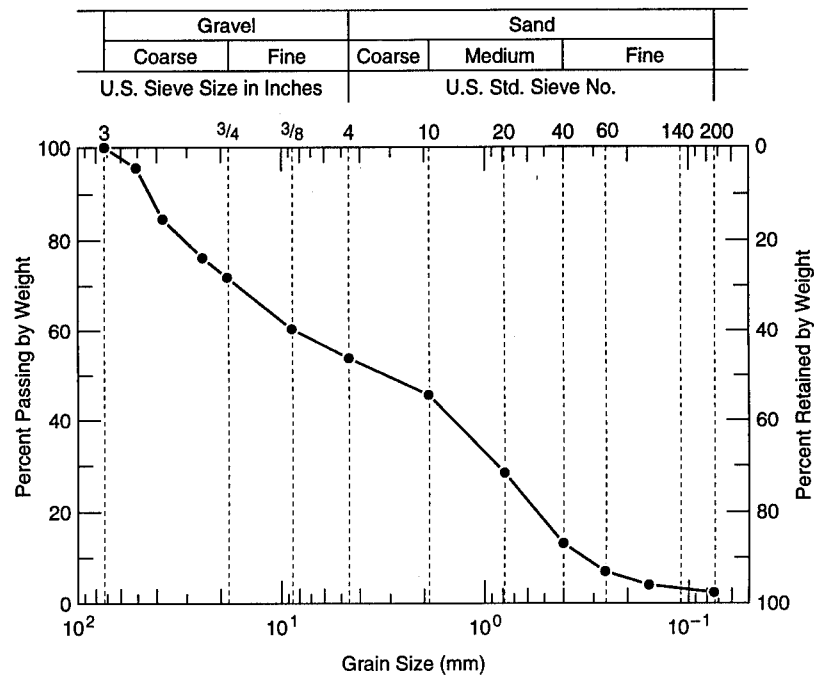


Figure A1. Grain size distribution of gravel.

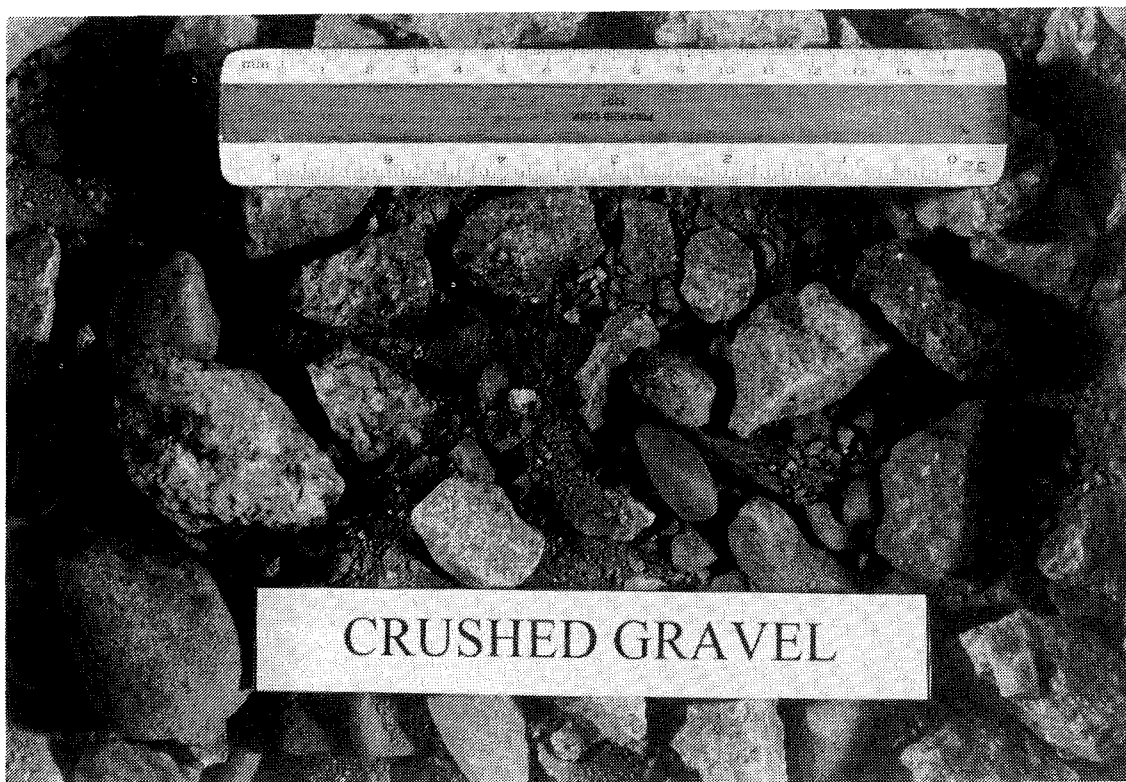
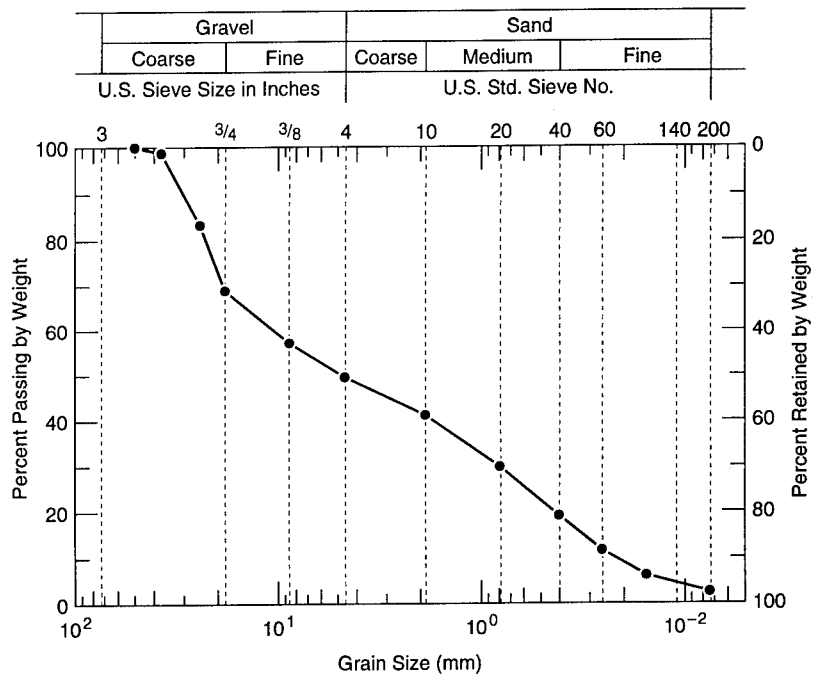


Figure A2. Grain size distribution of crushed gravel.



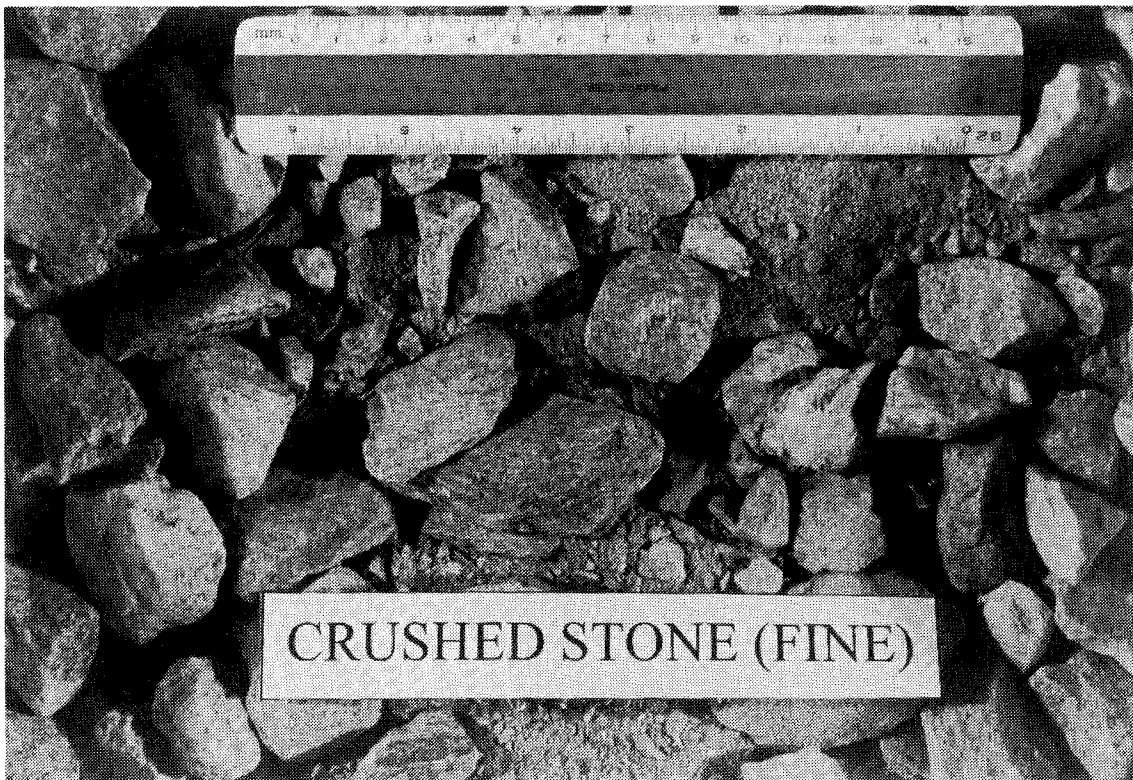
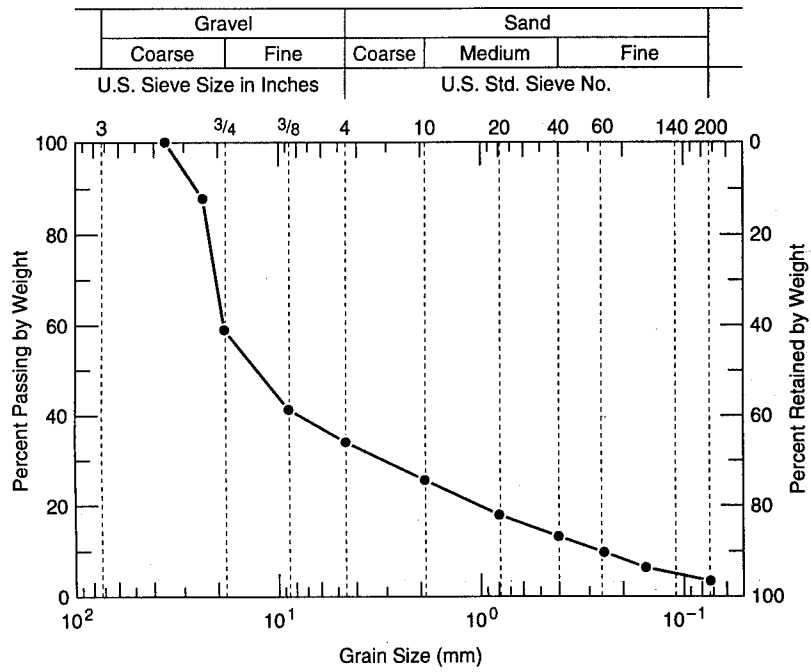


Figure A3. Grain size distribution of fine crushed stone.

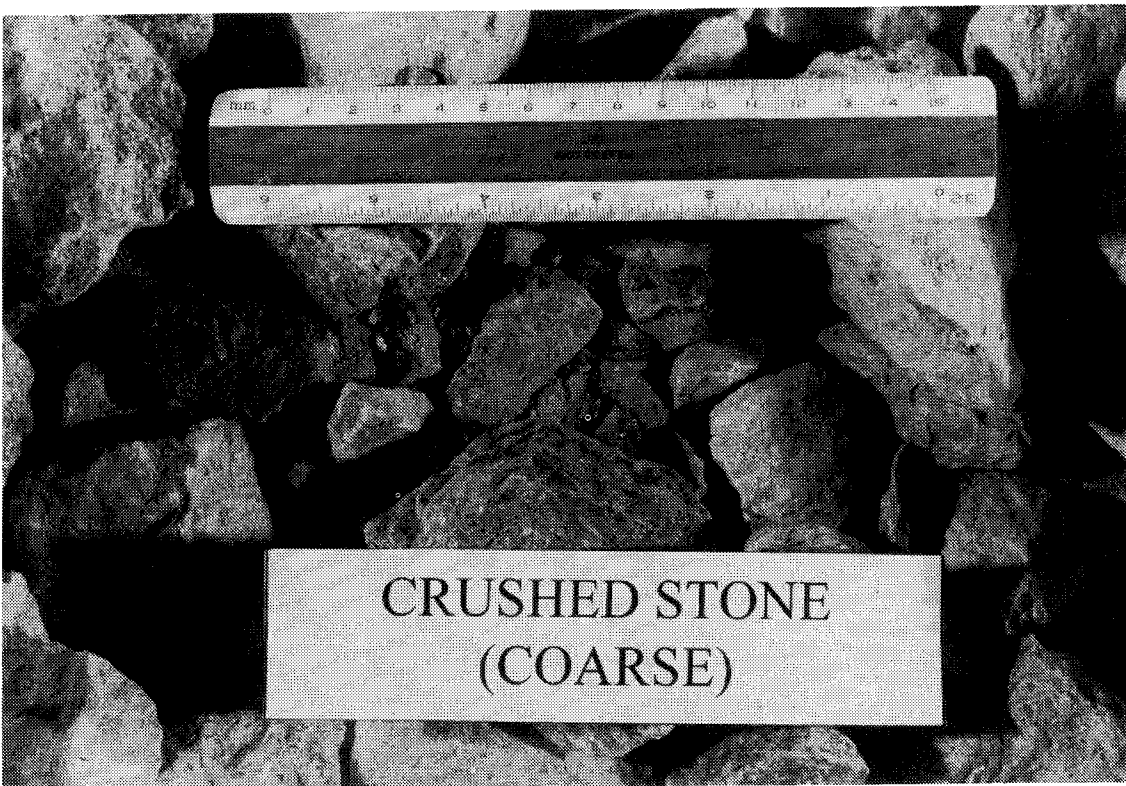
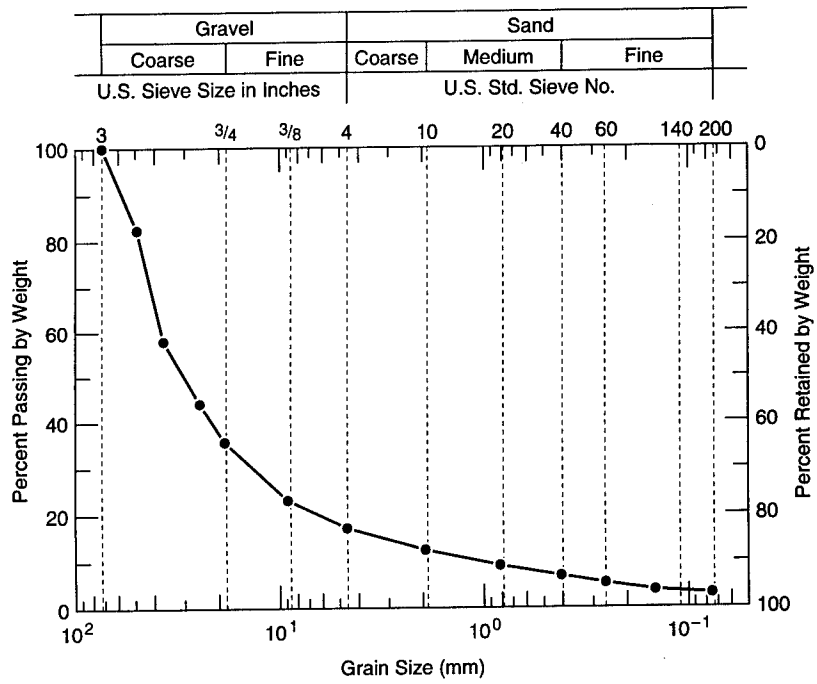


Figure A4. Grain size distribution of coarse crushed stone.

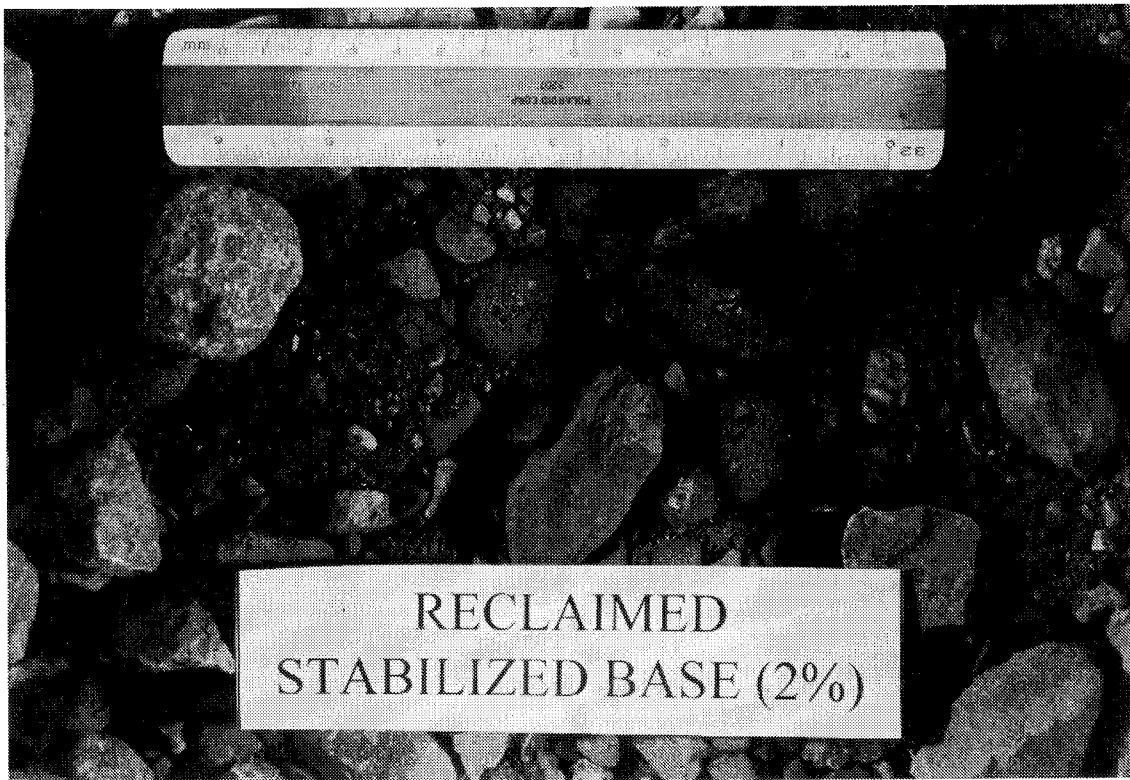
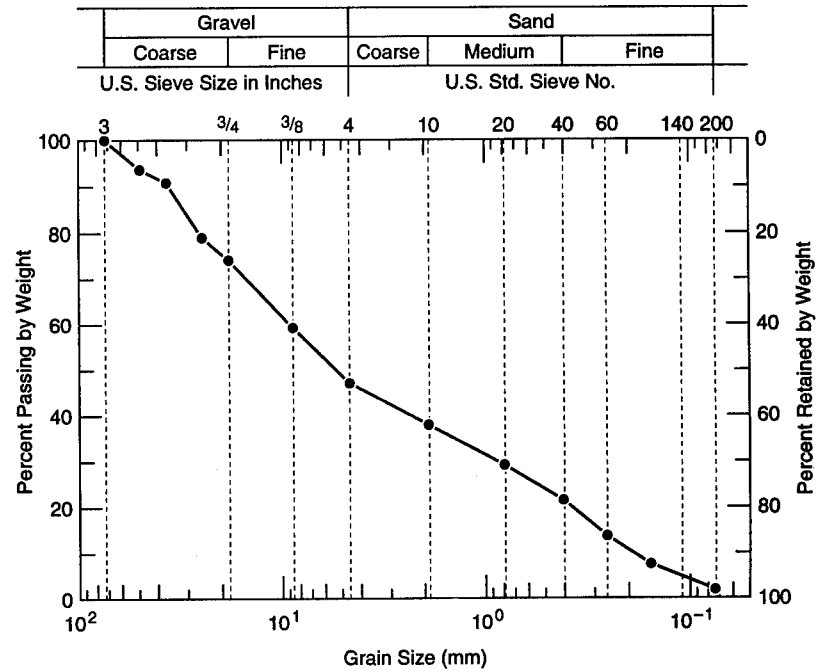


Figure A5. Grain size distribution of 2% RSB.

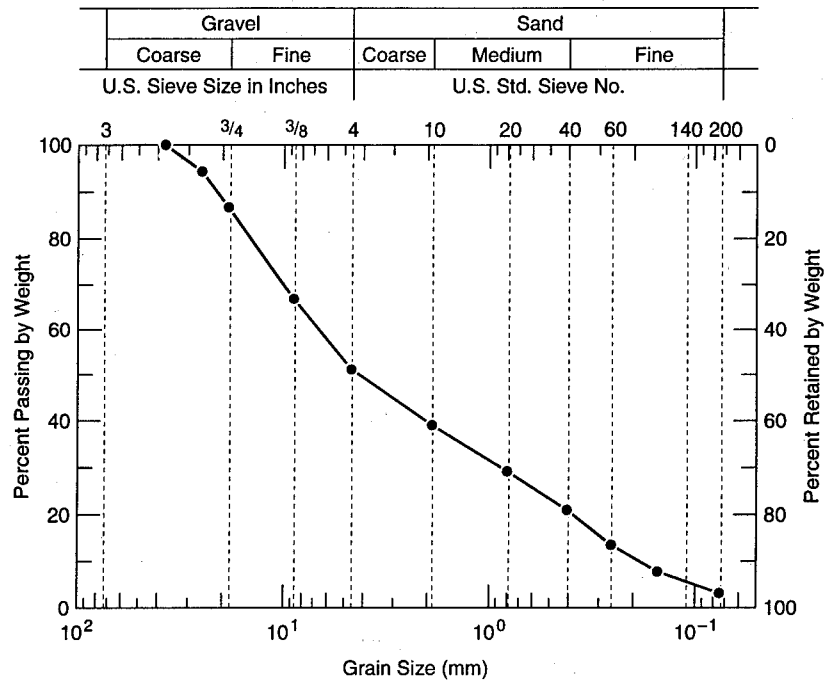


Figure A6. Grain size distribution of 3% RSB.

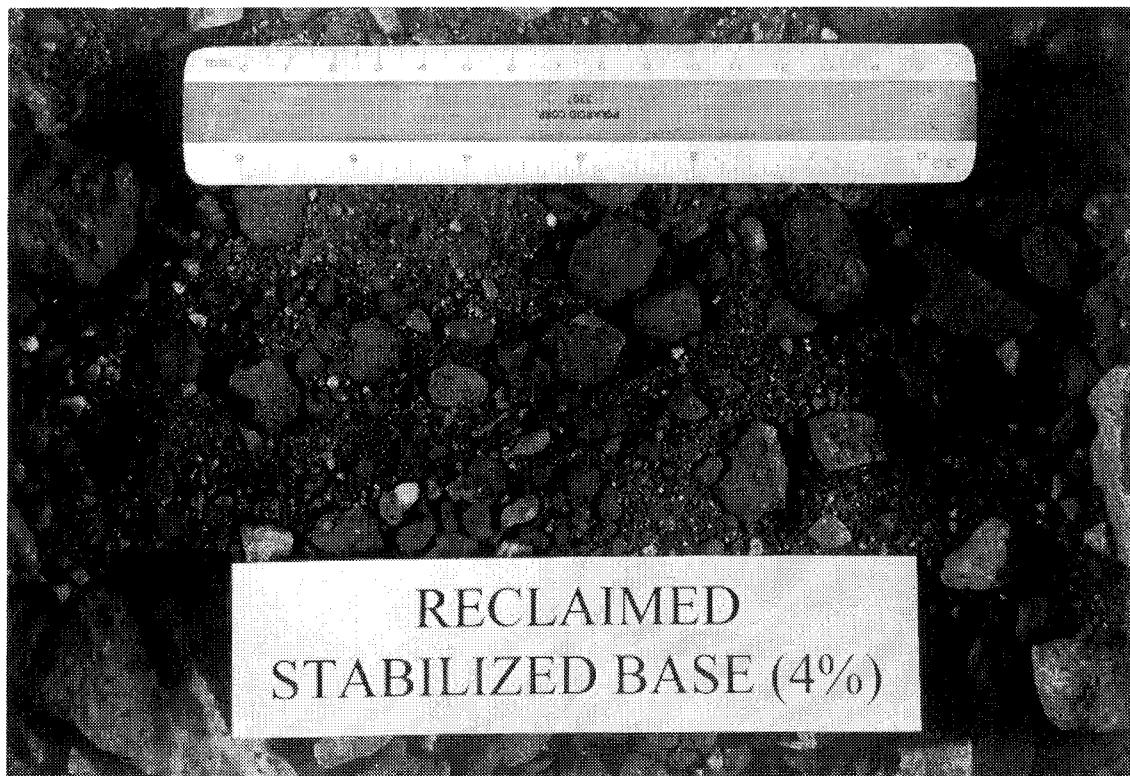
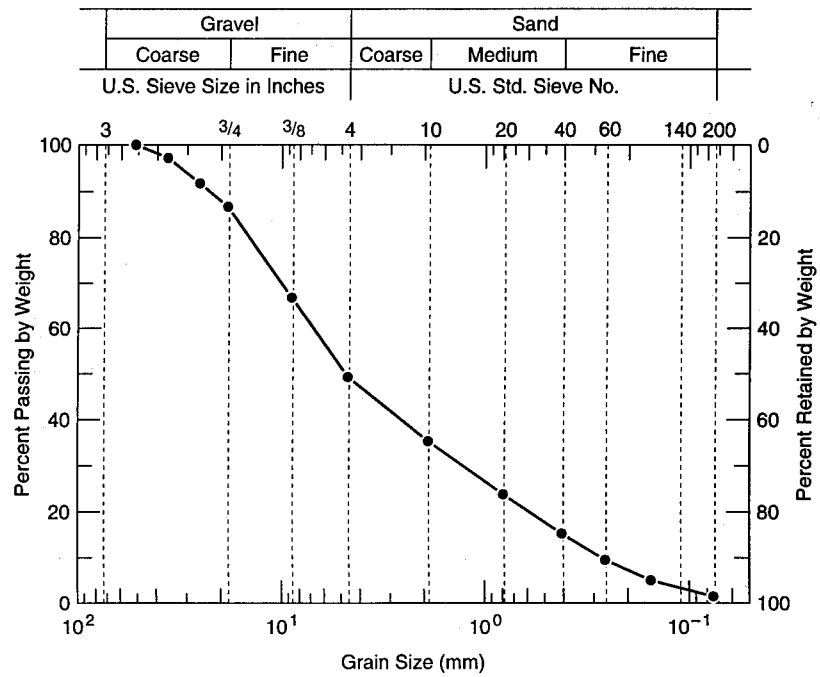


Figure A7. Grain size distribution of 4% RSB.

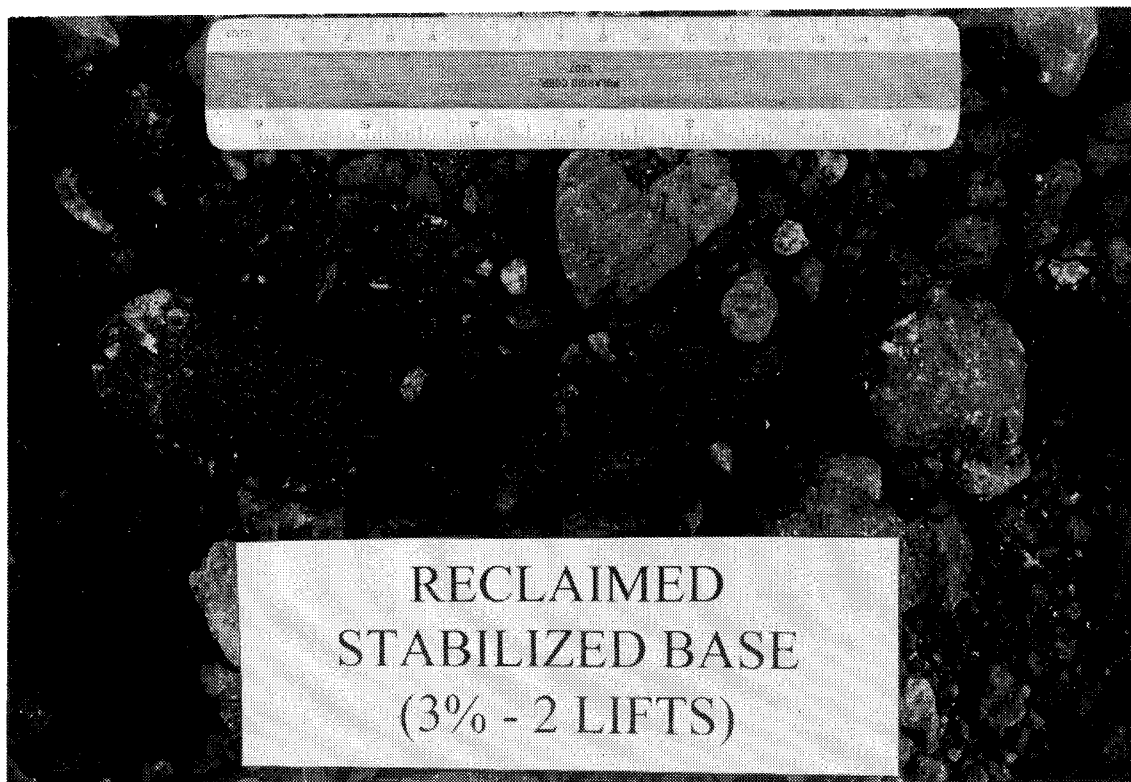
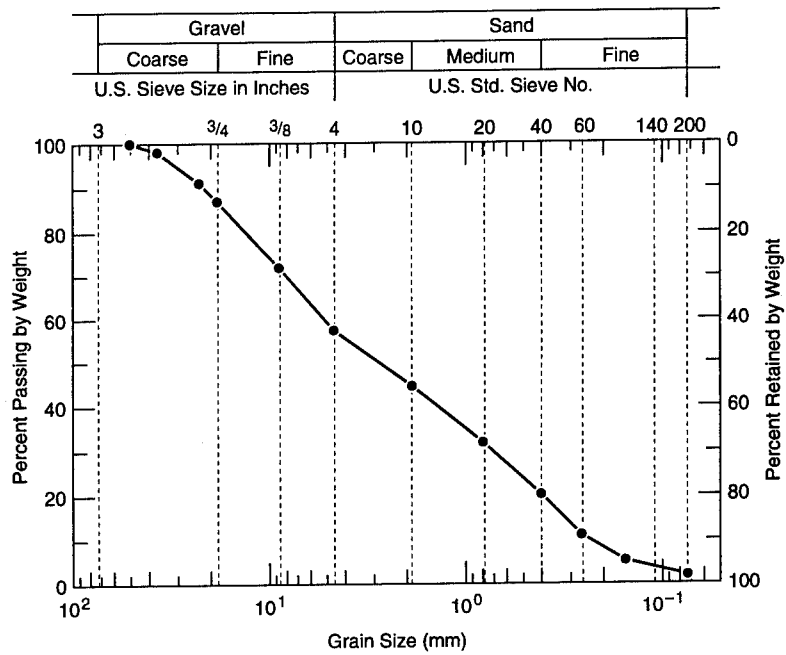


Figure A8. Grain size distribution of 3% RSB—two lifts.

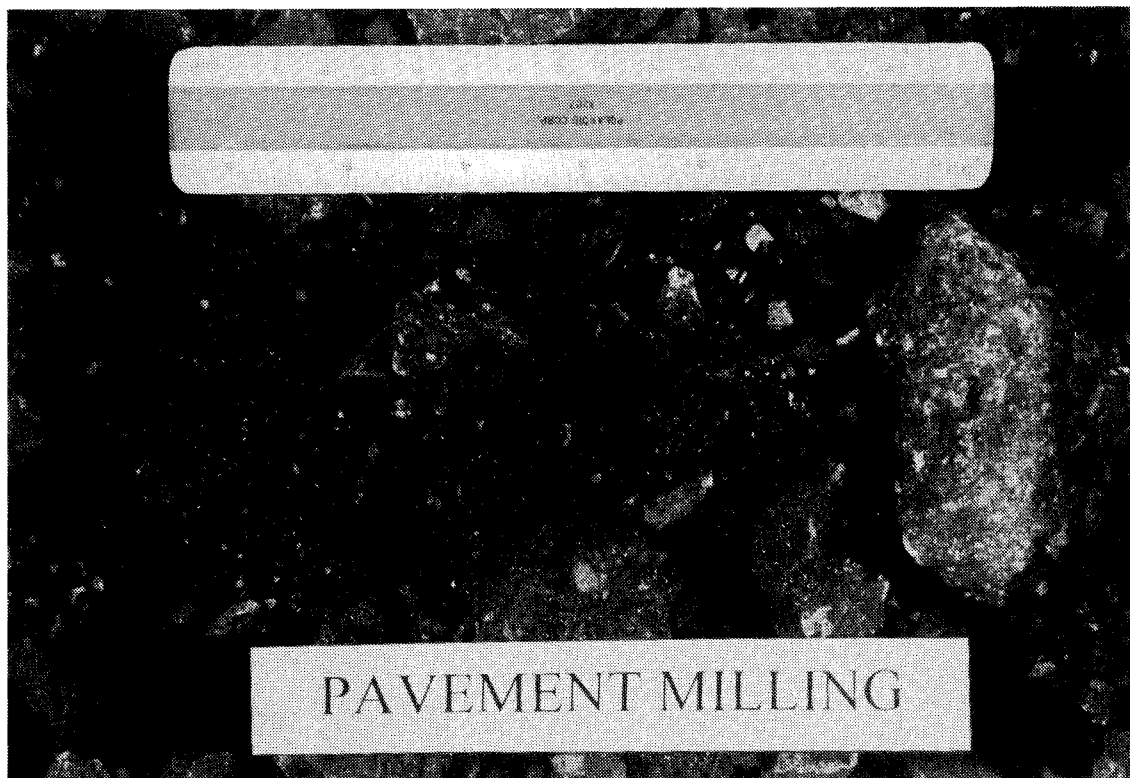
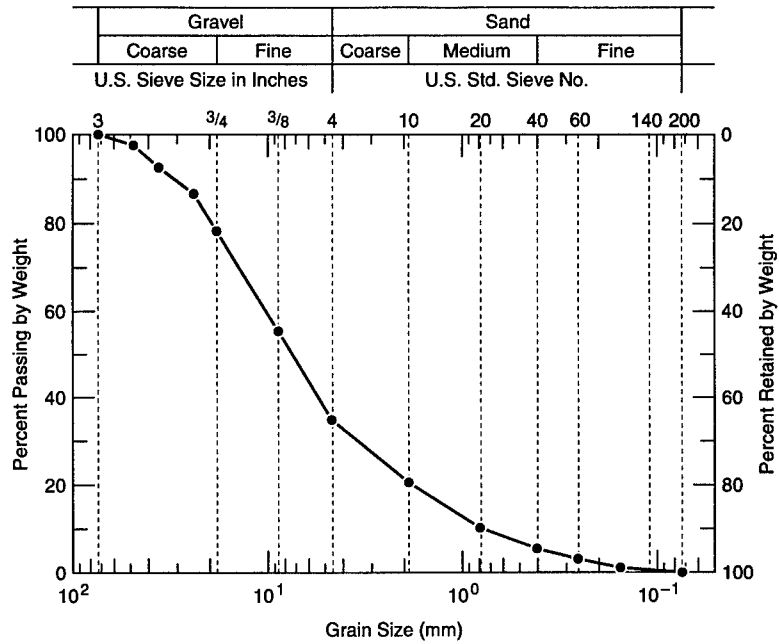


Figure A9. Grain size distribution of pavement millings.

**APPENDIX B: NORMALIZED HWD DEFLECTION MEASUREMENTS.**

**Gravel**

| SEC | STA | DF1<br>mils | DF2<br>mils | DF3<br>mils | DF4<br>mils | DF5<br>mils | DF6<br>mils | DF7<br>mils | BASIN<br>in^2 |
|-----|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 1   | 10  | 45.5        | 21.17       | 11.8        | 6.87        | 4.9         | 2.9         | 1.36        | 0.5220        |
| 1   | 15  | 43.44       | 18.15       | 12.38       | 7.68        | 4.59        | 2.46        | 1.15        | 0.4900        |
| 1   | 20  | 45.26       | 18.05       | 10.3        | 5.69        | 4.02        | 2.47        | 1.12        | 0.4690        |
| 1   | 25  | 43.37       | 19.62       | 10.57       | 5.62        | 3.79        | 2.19        | 1.13        | 0.4650        |
| 1   | 30  | 44.16       | 21.74       | 10.4        | 5.97        | 3.89        | 2.13        | 1.03        | 0.4810        |
| 1   | 35  | 37.41       | 19.78       | 10.46       | 4.69        | 3.4         | 1.98        | 1.08        | 0.4280        |
| 1   | 40  | 38.62       | 18.16       | 10.27       | 5.83        | 3.78        | 2.12        | 1.17        | 0.4360        |
| 1   | 45  | 42.07       | 27.9        | 12.64       | 6.46        | 4.55        | 2.31        | 1.13        | 0.5340        |
| 1   | 50  | 48.55       | 26.59       | 16.11       | 9.12        | 5.27        | 2.59        | 1.24        | 0.5980        |
| 1   | 55  | 44.98       | 22.86       | 14.26       | 9.08        | 5.91        | 2.94        | 2.17        | 0.5750        |
| 1   | 60  | 44.49       | 24.73       | 13.33       | 6.52        | 3.64        | 2.06        | 0.95        | 0.5130        |
| 1   | 65  | 44.66       | 24.61       | 13.92       | 6.73        | 3.74        | 2.06        | 1.04        | 0.5200        |
| 1   | 70  | 51.7        | 25.95       | 15.41       | 8.54        | 5.05        | 2.51        | 1.23        | 0.5960        |
| 1   | 75  | 49.83       | 30.24       | 11.64       | 6.4         | 4.53        | 2.06        | 1.04        | 0.5680        |
| 1   | 80  | 49.78       | 23.51       | 11.98       | 6.23        | 4.04        | 2.4         | 0.85        | 0.5270        |
| 1   | 85  | 63.95       | 34.56       | 21.47       | 12.34       | 6.83        | 2.94        | 1.65        | 0.7790        |
| 1   | 90  | 65.9        | 37.59       | 18.56       | 8.22        | 2.44        | 1.99        | 0.92        | 0.7000        |

**Crushed Gravel**

| SEC | STA | DF1<br>mils | DF2<br>mils | DF3<br>mils | DF4<br>mils | DF5<br>mils | DF6<br>mils | DF7<br>mils | BASIN<br>in^2 |
|-----|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 2   | 10  | 35.86       | 16.06       | 9.66        | 5.4         | 3.52        | 2.2         | 1.39        | 0.4090        |
| 2   | 15  | 38.39       | 20.47       | 12.23       | 6.8         | 4.77        | 2.42        | 1.22        | 0.4790        |
| 2   | 20  | 35.16       | 16.74       | 10.32       | 6.4         | 4.21        | 2.65        | 1.44        | 0.4340        |
| 2   | 25  | 35.89       | 19.84       | 11.22       | 6.25        | 4.11        | 2.53        | 1.34        | 0.4550        |
| 2   | 30  | 35.08       | 18.6        | 11.12       | 6.55        | 4.36        | 2.78        | 1.47        | 0.4540        |
| 2   | 35  | 36.93       | 20.82       | 11.42       | 6.49        | 4.3         | 2.65        | 1.45        | 0.4720        |
| 2   | 40  | 39.87       | 20.45       | 12.11       | 7.44        | 4.56        | 2.83        | 1.36        | 0.4960        |
| 2   | 45  | 42.89       | 23.57       | 14.89       | 8.56        | 5.55        | 3.04        | 1.54        | 0.5620        |
| 2   | 50  | 44.15       | 25.02       | 14          | 9.05        | 6.06        | 2.96        | 1.62        | 0.5780        |
| 2   | 55  | 42.83       | 27.41       | 16.03       | 8.78        | 5.01        | 2.87        | 1.39        | 0.5820        |
| 2   | 60  | 48.1        | 29.48       | 16.75       | 9.74        | 5.81        | 3.27        | 1.65        | 0.6420        |
| 2   | 65  | 46.85       | 26.93       | 14.23       | 7.41        | 4.66        | 2.86        | 1.35        | 0.5740        |
| 2   | 70  | 40.09       | 23.81       | 13.92       | 6.89        | 4.51        | 2.71        | 1.15        | 0.5170        |
| 2   | 75  | 46.07       | 26.11       | 15.53       | 8.5         | 4.99        | 2.83        | 1.5         | 0.5840        |
| 2   | 80  | 42.48       | 23.13       | 14.85       | 8.73        | 5.48        | 3.12        | 1.64        | 0.5600        |
| 2   | 85  | 52.55       | 31.56       | 20.47       | 10.92       | 6.35        | 3.12        | 1.88        | 0.7030        |
| 2   | 90  | 46.95       | 35.22       | 20          | 10.29       | 5.81        | 2.8         | 1.47        | 0.6810        |



**Crushed Stone (Fine)**

| SEC | STA | DF1<br>mils | DF2<br>mils | DF3<br>mils | DF4<br>mils | DF5<br>mils | DF6<br>mils | DF7<br>mils | BASIN<br>in^2 |
|-----|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 3   | 10  | 40          | 19.4        | 11.24       | 6.84        | 4.46        | 2.7         | 1.36        | 0.4790        |
| 3   | 15  | 39.33       | 21.95       | 11.32       | 6.24        | 3.98        | 2.23        | 1.35        | 0.4750        |
| 3   | 20  | 40.5        | 22.27       | 12.56       | 7.28        | 4.63        | 2.82        | 1.38        | 0.5110        |
| 3   | 25  | 35.43       | 18.59       | 10.31       | 5.43        | 3.47        | 2.19        | 1.13        | 0.4220        |
| 3   | 30  | 36.68       | 20.55       | 11.15       | 6.47        | 3.72        | 2.23        | 1.26        | 0.4530        |
| 3   | 35  | 38.7        | 20.14       | 10.99       | 6.13        | 3.9         | 2.42        | 1.2         | 0.4600        |
| 3   | 40  | 39.91       | 22.72       | 12.48       | 6.76        | 4.23        | 2.43        | 1.2         | 0.4950        |
| 3   | 45  | 39.14       | 21.9        | 11.94       | 7.2         | 4.78        | 2.84        | 1.36        | 0.5010        |
| 3   | 50  | 43.12       | 21.47       | 13.13       | 6.59        | 4.04        | 2.49        | 1.31        | 0.5030        |
| 3   | 55  | 40.98       | 23.54       | 12.76       | 7.61        | 5.09        | 2.59        | 1.37        | 0.5230        |
| 3   | 60  | 59.39       | 41.77       | 21.7        | 10.93       | 5.94        | 2.99        | 1.56        | 0.7880        |
| 3   | 65  | 52.76       | 36.1        | 18.77       | 10.12       | 6.14        | 3.1         | 1.35        | 0.7090        |
| 3   | 70  | 51.01       | 30.37       | 18.53       | 10.39       | 6.59        | 2.97        | 1.36        | 0.6700        |
| 3   | 75  | 53.89       | 29.35       | 16.31       | 7.66        | 3.74        | 1.99        | 1.42        | 0.6060        |
| 3   | 80  | 39.67       | 25.84       | 13.41       | 6.85        | 3.96        | 2.25        | 1.21        | 0.5130        |
| 3   | 85  | 65.9        | 44.71       | 25.75       | 13.32       | 7.04        | 2.89        | 1.39        | 0.8730        |
| 3   | 90  | 62.12       | 40.97       | 24.69       | 12.21       | 6.48        | 3.07        | 1.34        | 0.8210        |

**Crushed Stone (Coarse)**

| SEC | STA | DF1<br>mils | DF2<br>mils | DF3<br>mils | DF4<br>mils | DF5<br>mils | DF6<br>mils | DF7<br>mils | BASIN<br>in^2 |
|-----|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 4   | 10  | 35.83       | 21.65       | 14.32       | 8.06        | 4.95        | 2.41        | 1.32        | 0.4970        |
| 4   | 15  | 32.59       | 23.05       | 13.85       | 8.06        | 5.03        | 2.88        | 1.38        | 0.5000        |
| 4   | 20  | 35.31       | 23.24       | 13.96       | 8.27        | 5.19        | 2.77        | 1.34        | 0.5130        |
| 4   | 25  | 38.15       | 24.25       | 13.92       | 7.98        | 4.9         | 2.73        | 1.35        | 0.5250        |
| 4   | 30  | 36.24       | 22.2        | 12.47       | 7.39        | 4.59        | 2.57        | 1.43        | 0.4900        |
| 4   | 35  | 34.73       | 22.14       | 13.35       | 7.97        | 4.8         | 2.66        | 1.38        | 0.4940        |
| 4   | 40  | 37.72       | 23.37       | 15.07       | 8.67        | 5.57        | 3.2         | 1.7         | 0.5460        |
| 4   | 45  | 41.75       | 28.98       | 18.13       | 10.15       | 5.98        | 3.17        | 1.71        | 0.6240        |
| 4   | 50  | 37.95       | 24.33       | 16.53       | 9.73        | 5.76        | 3.08        | 1.63        | 0.5660        |
| 4   | 55  | 39.26       | 24.93       | 15.73       | 8.49        | 4.98        | 2.57        | 1.2         | 0.5420        |
| 4   | 60  | 39.02       | 24.89       | 13.68       | 6.02        | 3.25        | 1.99        | 1.14        | 0.4890        |
| 4   | 65  | 34.94       | 23.4        | 15.23       | 8.21        | 5.48        | 2.74        | 1.23        | 0.5190        |
| 4   | 70  | 35.52       | 18.81       | 9.48        | 4.98        | 3.73        | 2.55        | 1.2         | 0.4260        |
| 4   | 75  | 42.27       | 29.8        | 17.54       | 8.44        | 4.65        | 2.46        | 1.25        | 0.5870        |
| 4   | 80  | 55.75       | 34.88       | 22.66       | 12.37       | 6.52        | 2.69        | 1.83        | 0.7490        |
| 4   | 85  | 57.56       | 38.53       | 22.12       | 9.48        | 5.08        | 2.85        | 1.36        | 0.7420        |
| 4   | 90  | 56.83       | 39.13       | 20.63       | 11.46       | 6.11        | 3.23        | 1.31        | 0.7630        |

**Reclaimed Stabilized Base (2%)**

| SEC | STA | DF1<br>mils | DF2<br>mils | DF3<br>mils | DF4<br>mils | DF5<br>mils | DF6<br>mils | DF7<br>mils | BASIN<br>in^2 |
|-----|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 5   | 10  | 32.32       | 20.17       | 12.62       | 7.56        | 4.72        | 2.55        | 1.36        | 0.4630        |
| 5   | 15  | 33.79       | 22.68       | 14          | 8.14        | 5.19        | 2.65        | 1.35        | 0.5010        |
| 5   | 20  | 34.39       | 19.93       | 12.71       | 7.99        | 4.94        | 2.65        | 1.17        | 0.4750        |
| 5   | 25  | 30.05       | 13.37       | 9.08        | 5.5         | 3.62        | 2.16        | 1.31        | 0.3660        |
| 5   | 30  | 30.58       | 17.68       | 11.17       | 6.51        | 4.08        | 2.41        | 1.48        | 0.4210        |
| 5   | 35  | 31.16       | 18.87       | 12.08       | 6.97        | 4.29        | 2.42        | 1.35        | 0.4380        |
| 5   | 40  | 33.33       | 20.62       | 14.15       | 8.36        | 4.98        | 2.6         | 1.39        | 0.4860        |
| 5   | 45  | 33.42       | 19.77       | 13.27       | 8.05        | 4.91        | 2.68        | 1.4         | 0.4760        |
| 5   | 50  | 34.53       | 21.47       | 12.99       | 7.49        | 4.58        | 2.44        | 1.37        | 0.4780        |
| 5   | 55  | 35.07       | 19.91       | 12.99       | 7.47        | 4.41        | 2.39        | 1.3         | 0.4680        |
| 5   | 60  | 39.38       | 24.67       | 15.86       | 8.93        | 5.07        | 2.49        | 1.34        | 0.5450        |
| 5   | 65  | 38.8        | 24.16       | 15.74       | 8.77        | 4.93        | 2.51        | 1.41        | 0.5380        |
| 5   | 70  | 40.94       | 24.36       | 16.22       | 9.4         | 5.47        | 2.83        | 1.51        | 0.5660        |
| 5   | 75  | 37.46       | 24.52       | 16          | 9.7         | 5.45        | 2.55        | 1.34        | 0.5460        |
| 5   | 80  | 39.26       | 25.59       | 16.71       | 9.41        | 5.44        | 2.56        | 1.4         | 0.5620        |
| 5   | 85  | 36.12       | 23.35       | 14.38       | 8.58        | 5.14        | 2.9         | 1.59        | 0.5260        |
| 5   | 90  | 33.12       | 23.32       | 14.37       | 8.54        | 5.37        | 2.99        | 1.17        | 0.5120        |

**Reclaimed Stabilized Base (3%)**

| SEC | STA | DF1<br>mils | DF2<br>mils | DF3<br>mils | DF4<br>mils | DF5<br>mils | DF6<br>mils | DF7<br>mils | BASIN<br>in^2 |
|-----|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 6   | 10  | 34.29       | 20.62       | 13.09       | 7.51        | 4.35        | 2.22        | 1.22        | 0.4650        |
| 6   | 15  | 30.2        | 16.34       | 10.39       | 6.21        | 3.91        | 2.26        | 1.37        | 0.4000        |
| 6   | 20  | 33.65       | 20.33       | 13.24       | 7.55        | 4.28        | 2.42        | 1.3         | 0.4660        |
| 6   | 25  | 40.02       | 21.99       | 14.17       | 8.19        | 4.97        | 2.59        | 1.35        | 0.5200        |
| 6   | 30  | 34.1        | 18.23       | 11.68       | 6.62        | 4.03        | 2.36        | 1.34        | 0.4390        |
| 6   | 35  | 34.98       | 20.12       | 13.01       | 7.34        | 4.36        | 2.59        | 1.44        | 0.4730        |
| 6   | 40  | 34.35       | 21.2        | 13.8        | 7.74        | 4.77        | 2.76        | 1.57        | 0.4920        |
| 6   | 45  | 36.54       | 21.53       | 14.14       | 8.61        | 5.23        | 2.88        | 1.63        | 0.5160        |
| 6   | 50  | 36.28       | 22.52       | 14.98       | 9.08        | 5.81        | 3.31        | 1.76        | 0.5430        |
| 6   | 55  | 38.46       | 24.27       | 15.9        | 8.94        | 5.11        | 2.71        | 1.48        | 0.5450        |
| 6   | 60  | 35.08       | 22.12       | 13.79       | 7.25        | 4.28        | 2.41        | 1.46        | 0.4850        |
| 6   | 65  | 35.5        | 22.4        | 14.13       | 7.45        | 4.43        | 2.49        | 1.44        | 0.4940        |
| 6   | 70  | 33.84       | 22.22       | 14.1        | 7.88        | 4.54        | 2.53        | 1.29        | 0.4880        |
| 6   | 75  | 39.2        | 23.37       | 14.33       | 8.13        | 5           | 2.68        | 1.48        | 0.5290        |
| 6   | 80  | 46.59       | 28.45       | 17.83       | 10.42       | 6.18        | 3.16        | 1.57        | 0.6400        |
| 6   | 85  | 37.71       | 23.67       | 14.8        | 8.37        | 4.98        | 2.59        | 1.48        | 0.5260        |
| 6   | 90  | 34.74       | 21.68       | 13.6        | 7.72        | 4.66        | 2.56        | 1.42        | 0.4880        |

**Reclaimed Stabilized Base (4%)**

| SEC | STA | DF1<br>mils | DF2<br>mils | DF3<br>mils | DF4<br>mils | DF5<br>mils | DF6<br>mils | DF7<br>mils | BASIN<br>in^2 |
|-----|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 7   | 10  | 31.31       | 21.69       | 14.16       | 8.53        | 5.14        | 2.56        | 1.42        | 0.4870        |
| 7   | 15  | 30.96       | 17.78       | 12.08       | 7.27        | 4.5         | 2.55        | 1.38        | 0.4370        |
| 7   | 20  | 28.62       | 18.74       | 12.45       | 7.27        | 4.39        | 2.42        | 1.41        | 0.4330        |
| 7   | 25  | 32.17       | 20.14       | 13.66       | 7.82        | 4.6         | 2.5         | 1.59        | 0.4700        |
| 7   | 30  | 32.52       | 22.16       | 14.45       | 8.5         | 4.89        | 2.35        | 1.26        | 0.4880        |
| 7   | 35  | 31.7        | 21.41       | 14.62       | 8.92        | 5.48        | 2.76        | 1.48        | 0.4990        |
| 7   | 40  | 31.05       | 21.09       | 14.45       | 9           | 5.56        | 2.95        | 1.51        | 0.4980        |
| 7   | 45  | 36.21       | 23.16       | 15.87       | 9.44        | 5.67        | 2.79        | 1.47        | 0.5390        |
| 7   | 50  | 35.41       | 23.13       | 16.09       | 9.48        | 5.29        | 2.7         | 1.44        | 0.5310        |
| 7   | 55  | 33.97       | 22.81       | 15.37       | 9.17        | 5.3         | 2.57        | 1.37        | 0.5150        |
| 7   | 60  | 32.78       | 18.38       | 12.29       | 7.31        | 4.75        | 2.63        | 1.35        | 0.4530        |
| 7   | 65  | 31.78       | 21.11       | 14.79       | 9.23        | 5.55        | 2.68        | 1.42        | 0.4980        |
| 7   | 70  | 31.77       | 21.81       | 14.98       | 8.89        | 5.32        | 2.76        | 1.48        | 0.5020        |
| 7   | 75  | 36.28       | 23.32       | 15.49       | 8.96        | 5.21        | 2.51        | 1.22        | 0.5230        |
| 7   | 80  | 34.4        | 21.94       | 15.25       | 9.19        | 5.47        | 2.7         | 1.41        | 0.5150        |
| 7   | 85  | 35.96       | 23.07       | 15.33       | 8.96        | 5.4         | 2.83        | 1.47        | 0.5300        |
| 7   | 90  | 33.64       | 24.34       | 16.77       | 10.2        | 5.91        | 2.79        | 1.4         | 0.5460        |

**Reclaimed Stabilized Base (3% - 2 lifts)**

| SEC | STA | DF1<br>mils | DF2<br>mils | DF3<br>mils | DF4<br>mils | DF5<br>mils | DF6<br>mils | DF7<br>mils | BASIN<br>in^2 |
|-----|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 8   | 10  | 38          | 23.55       | 14.57       | 8.61        | 5.46        | 2.99        | 1.46        | 0.5380        |
| 8   | 15  | 37.53       | 20.24       | 13.55       | 8.1         | 4.94        | 2.61        | 1.4         | 0.4960        |
| 8   | 20  | 39.04       | 24.89       | 15.68       | 8.69        | 4.88        | 2.38        | 1.27        | 0.5380        |
| 8   | 25  | 33.52       | 20.27       | 12.62       | 7.26        | 4.41        | 2.25        | 1.29        | 0.4580        |
| 8   | 30  | 35.84       | 20.82       | 13.13       | 7.48        | 4.46        | 2.26        | 1.31        | 0.4750        |
| 8   | 35  | 33.78       | 20.26       | 12.92       | 7.8         | 4.87        | 2.44        | 1.31        | 0.4720        |
| 8   | 40  | 38.65       | 24.94       | 15.18       | 8.07        | 4.5         | 2.36        | 1.33        | 0.5270        |
| 8   | 45  | 30.13       | 18.27       | 11.66       | 7.06        | 4.48        | 2.42        | 1.4         | 0.4310        |
| 8   | 50  | 33.43       | 21.77       | 14.25       | 8.67        | 5.31        | 2.89        | 1.63        | 0.5070        |
| 8   | 55  | 37.84       | 22.22       | 15.37       | 9.23        | 5.49        | 2.89        | 1.55        | 0.5370        |
| 8   | 60  | 32.54       | 18.55       | 11.6        | 6.87        | 4.27        | 2.52        | 1.42        | 0.4410        |
| 8   | 65  | 41.93       | 28.63       | 17.16       | 8.87        | 5.38        | 2.83        | 1.52        | 0.5960        |
| 8   | 70  | 41.84       | 27.11       | 16.92       | 9.31        | 5.48        | 2.69        | 1.33        | 0.5840        |
| 8   | 75  | 38.57       | 23.65       | 13.39       | 7.16        | 4.23        | 2.25        | 1.26        | 0.5000        |
| 8   | 80  | 50.68       | 34.15       | 21.74       | 11.22       | 5.77        | 2.46        | 1.39        | 0.6970        |
| 8   | 85  | 61.95       | 41.31       | 25.12       | 12.08       | 5.95        | 2.62        | 1.44        | 0.8120        |
| 8   | 90  | 53.55       | 33.7        | 18          | 8.87        | 4.62        | 2.33        | 1.36        | 0.6590        |

**Asphalt Concrete**

| SEC | STA | DF1<br>mils | DF2<br>mils | DF3<br>mils | DF4<br>mils | DF5<br>mils | DF6<br>mils | DF7<br>mils | BASIN<br>in^2 |
|-----|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 9   | 10  | 10.99       | 9.27        | 8.1         | 6.63        | 5.23        | 3.17        | 1.22        | 0.2990        |
| 9   | 15  | 9.35        | 8.09        | 7.11        | 5.81        | 4.51        | 2.71        | 1           | 0.2580        |
| 9   | 20  | 10.51       | 8.97        | 7.8         | 6.27        | 4.71        | 2.64        | 1           | 0.2740        |
| 9   | 25  | 11.39       | 9.49        | 7.95        | 6.17        | 4.48        | 2.4         | 0.99        | 0.2750        |
| 9   | 30  | 10.49       | 8.74        | 7.41        | 5.77        | 4.22        | 2.29        | 0.88        | 0.2560        |
| 9   | 35  | 11          | 8.97        | 7.61        | 5.94        | 4.39        | 2.35        | 0.91        | 0.2640        |
| 9   | 40  | 11.21       | 9.26        | 7.78        | 6.1         | 4.44        | 2.45        | 0.99        | 0.2720        |
| 9   | 45  | 10.9        | 8.93        | 7.61        | 6.03        | 4.46        | 2.45        | 0.95        | 0.2670        |
| 9   | 50  | 10.33       | 8.28        | 6.99        | 5.45        | 4.01        | 2.25        | 0.92        | 0.2460        |
| 9   | 55  | 9.52        | 7.78        | 6.7         | 5.34        | 3.97        | 2.19        | 0.79        | 0.2350        |
| 9   | 60  | 8.66        | 7.03        | 6.03        | 4.78        | 3.57        | 2.03        | 0.78        | 0.2140        |
| 9   | 65  | 8.23        | 6.83        | 5.96        | 4.83        | 3.68        | 2.13        | 0.85        | 0.2140        |
| 9   | 70  | 7.49        | 6.07        | 5.28        | 4.28        | 3.29        | 1.96        | 0.79        | 0.1930        |
| 9   | 75  | 7.31        | 5.64        | 4.94        | 4.04        | 3.12        | 1.92        | 0.83        | 0.1850        |
| 9   | 80  | 8.4         | 6.56        | 5.72        | 4.7         | 3.66        | 2.22        | 0.93        | 0.2140        |
| 9   | 85  | 9.16        | 7.89        | 6.96        | 5.68        | 4.45        | 2.71        | 1.09        | 0.2550        |
| 9   | 90  | 8.4         | 7.31        | 6.47        | 5.39        | 4.26        | 2.66        | 1.06        | 0.2410        |

**Pavement Milling**

| SEC | STA | DF1<br>mils | DF2<br>mils | DF3<br>mils | DF4<br>mils | DF5<br>mils | DF6<br>mils | DF7<br>mils | BASIN<br>in^2 |
|-----|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 10  | 10  | 36.57       | 22.18       | 15.43       | 9.15        | 5.3         | 2.69        | 1.43        | 0.5250        |
| 10  | 15  | 33.97       | 22.76       | 15.14       | 8.5         | 4.83        | 2.48        | 1.38        | 0.5040        |
| 10  | 20  | 33.43       | 22.14       | 15.41       | 9.36        | 5.4         | 2.43        | 1.26        | 0.5070        |
| 10  | 25  | 32.03       | 21.82       | 14.45       | 8.42        | 4.78        | 2.31        | 1.19        | 0.4810        |
| 10  | 30  | 34.98       | 24.6        | 16.7        | 9.8         | 5.25        | 2.34        | 1.19        | 0.5340        |
| 10  | 35  | 31.16       | 20.63       | 13.88       | 8.14        | 4.66        | 2.29        | 1.33        | 0.4660        |
| 10  | 40  | 39.32       | 23.67       | 15.18       | 7.99        | 4.14        | 2.12        | 1.25        | 0.5140        |
| 10  | 45  | 31.01       | 20.43       | 13.65       | 7.56        | 4.39        | 2.38        | 1.25        | 0.4580        |
| 10  | 50  | 36.71       | 23.94       | 15.82       | 9.17        | 5.06        | 2.34        | 1.39        | 0.5290        |
| 10  | 55  | 36.18       | 23.65       | 16.61       | 9.78        | 5.31        | 2.61        | 1.43        | 0.5400        |
| 10  | 60  | 32.74       | 22.46       | 15.55       | 9.48        | 5.51        | 2.77        | 1.46        | 0.5170        |
| 10  | 65  | 29.42       | 18.75       | 12.73       | 7.64        | 4.56        | 2.41        | 1.35        | 0.4400        |
| 10  | 70  | 34.56       | 22.91       | 15.21       | 8.27        | 4.34        | 2.31        | 1.38        | 0.4990        |
| 10  | 75  | 32.91       | 19.52       | 13.15       | 7.76        | 4.5         | 2.35        | 1.27        | 0.4590        |
| 10  | 80  | 29.68       | 18.2        | 12.11       | 6.72        | 3.84        | 2.04        | 1.11        | 0.4130        |
| 10  | 85  | 33.21       | 21.76       | 15.16       | 8.83        | 5           | 2.47        | 1.32        | 0.4970        |
| 10  | 90  | 26.51       | 20.18       | 14.06       | 8.83        | 5.3         | 2.43        | 1.26        | 0.4570        |

| Subgrade |     | DF1  | DF2  | DF3  | DF4  | DF5  | DF6  | DF7  | BASIN  |
|----------|-----|------|------|------|------|------|------|------|--------|
| SEC      | STA | mils | mils | mils | mils | mils | mils | mils | in^2   |
| 1        | 10  | 35.3 | 14.7 | 8.0  | 5.3  | 2.9  | 1.9  | 1.3  | 0.5053 |
| 1        | 15  | 30.8 | 12.2 | 6.3  | 4.1  | 2.1  | 1.5  | 1.1  | 0.4201 |
| 1        | 20  | 31.5 | 14.4 | 7.1  | 4.4  | 2.2  | 1.6  | 1.2  | 0.4542 |
| 1        | 25  | 30.5 | 11.5 | 5.9  | 3.9  | 2.2  | 1.6  | 1.1  | 0.4077 |
| 1        | 30  | 26.0 | 10.5 | 5.2  | 3.3  | 1.9  | 1.4  | 1.1  | 0.3565 |
| 1        | 35  | 27.1 | 8.9  | 4.2  | 2.6  | 1.7  | 1.3  | 0.9  | 0.3333 |
| 1        | 40  | 22.9 | 8.8  | 4.9  | 3.3  | 2.0  | 1.4  | 1.1  | 0.3240 |
| 1        | 45  | 28.7 | 12.4 | 7.0  | 4.5  | 2.3  | 1.7  | 1.3  | 0.4216 |
| 1        | 50  | 37.0 | 17.4 | 9.9  | 5.8  | 2.6  | 1.7  | 1.2  | 0.5487 |
| 1        | 55  | 37.9 | 15.2 | 6.9  | 4.4  | 2.4  | 1.7  | 1.3  | 0.5007 |
| 1        | 60  | 32.1 | 11.6 | 4.8  | 2.8  | 1.7  | 1.3  | 1.0  | 0.3937 |
| 1        | 65  | 35.4 | 13.1 | 5.8  | 3.4  | 1.9  | 1.5  | 1.1  | 0.4433 |
| 1        | 70  | 44.2 | 19.7 | 8.8  | 5.2  | 2.6  | 1.7  | 1.2  | 0.6014 |
| 1        | 75  | 47.0 | 21.8 | 10.5 | 5.2  | 1.7  | 1.2  | 0.9  | 0.6262 |
| 1        | 80  | 43.6 | 20.5 | 8.4  | 4.2  | 1.9  | 1.3  | 1.0  | 0.5797 |
| 1        | 85  | 53.5 | 25.3 | 11.5 | 6.5  | 2.9  | 2.1  | 1.6  | 0.7456 |
| 1        | 90  | 53.8 | 20.7 | 7.9  | 4.5  | 2.4  | 1.7  | 1.3  | 0.6526 |

| Subgrade |     | DF1  | DF2  | DF3  | DF4  | DF5  | DF6  | DF7  | BASIN  |
|----------|-----|------|------|------|------|------|------|------|--------|
| SEC      | STA | mils | mils | mils | mils | mils | mils | mils | in^2   |
| 2        | 10  | 27.7 | 11.5 | 6.3  | 3.9  | 2.2  | 1.7  | 1.3  | 0.3968 |
| 2        | 15  | 25.4 | 11.5 | 6.0  | 4.1  | 2.2  | 1.7  | 1.4  | 0.3844 |
| 2        | 20  | 30.2 | 11.2 | 5.7  | 3.8  | 2.2  | 1.6  | 1.2  | 0.4046 |
| 2        | 25  | 24.1 | 9.0  | 5.7  | 3.7  | 2.2  | 1.7  | 1.3  | 0.3488 |
| 2        | 30  | 24.8 | 10.6 | 5.7  | 4.0  | 2.4  | 1.9  | 1.4  | 0.3751 |
| 2        | 35  | 33.6 | 13.5 | 6.9  | 4.1  | 2.2  | 1.7  | 1.3  | 0.4557 |
| 2        | 40  | 39.5 | 14.8 | 7.4  | 4.6  | 2.4  | 1.7  | 1.4  | 0.5131 |
| 2        | 45  | 42.1 | 18.7 | 9.6  | 5.6  | 2.8  | 2.0  | 1.6  | 0.5952 |
| 2        | 50  | 44.4 | 14.5 | 7.0  | 4.2  | 2.3  | 1.7  | 1.5  | 0.5332 |
| 2        | 55  | 44.5 | 19.3 | 7.2  | 4.1  | 2.0  | 1.6  | 1.2  | 0.5720 |
| 2        | 60  | 61.4 | 27.0 | 12.0 | 6.5  | 2.8  | 1.9  | 1.5  | 0.8076 |
| 2        | 65  | 53.2 | 21.1 | 9.1  | 5.0  | 2.6  | 1.7  | 1.2  | 0.6665 |
| 2        | 70  | 35.7 | 14.6 | 6.9  | 4.1  | 2.2  | 1.6  | 1.2  | 0.4759 |
| 2        | 75  | 36.3 | 15.6 | 7.4  | 4.4  | 2.3  | 1.7  | 1.5  | 0.4991 |
| 2        | 80  | 45.9 | 20.8 | 10.2 | 5.9  | 3.0  | 2.2  | 1.6  | 0.6479 |
| 2        | 85  | 67.8 | 26.3 | 11.0 | 5.9  | 2.8  | 2.0  | 1.6  | 0.8308 |
| 2        | 90  | 72.8 | 18.4 | 7.4  | 4.3  | 2.3  | 1.5  | 1.1  | 0.7378 |

**Subgrade**

| SEC | STA | DF1<br>mils | DF2<br>mils | DF3<br>mils | DF4<br>mils | DF5<br>mils | DF6<br>mils | DF7<br>mils | BASIN<br>in^2 |
|-----|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 3   | 10  | 33.2        | 14.0        | 7.4         | 4.3         | 2.4         | 1.8         | 1.3         | 0.4650        |
| 3   | 15  | 33.0        | 14.3        | 6.6         | 4.0         | 2.2         | 1.8         | 1.3         | 0.4573        |
| 3   | 20  | 35.4        | 11.8        | 5.8         | 3.7         | 2.2         | 1.7         | 1.3         | 0.4418        |
| 3   | 25  | 28.3        | 9.9         | 4.5         | 2.9         | 1.9         | 1.4         | 1.1         | 0.3581        |
| 3   | 30  | 25.1        | 10.0        | 4.8         | 3.1         | 1.9         | 1.5         | 1.1         | 0.3457        |
| 3   | 35  | 30.6        | 10.7        | 5.6         | 3.5         | 1.9         | 1.5         | 1.1         | 0.3922        |
| 3   | 40  | 33.0        | 13.6        | 6.7         | 4.0         | 2.1         | 1.6         | 1.1         | 0.4464        |
| 3   | 45  | 32.3        | 14.7        | 7.7         | 4.8         | 2.7         | 1.9         | 1.5         | 0.4790        |
| 3   | 50  | 37.1        | 12.4        | 5.7         | 3.7         | 2.2         | 1.7         | 1.3         | 0.4557        |
| 3   | 55  | 35.1        | 15.9        | 7.8         | 4.4         | 2.0         | 1.5         | 1.3         | 0.4898        |
| 3   | 60  | 71.3        | 28.0        | 11.0        | 5.2         | 2.2         | 1.6         | 1.3         | 0.8463        |
| 3   | 65  | 48.4        | 20.1        | 8.9         | 5.2         | 2.6         | 1.8         | 1.3         | 0.6309        |
| 3   | 70  | 55.1        | 26.0        | 11.0        | 5.6         | 2.5         | 1.7         | 1.3         | 0.7394        |
| 3   | 75  | 59.7        | 18.0        | 3.0         | 2.2         | 1.9         | 1.5         | 1.2         | 0.6061        |
| 3   | 80  | 52.2        | 18.8        | 7.8         | 4.4         | 2.2         | 1.5         | 1.1         | 0.6200        |
| 3   | 85  | 66.5        | 26.9        | 10.4        | 5.6         | 2.5         | 1.7         | 1.3         | 0.8107        |
| 3   | 90  | 73.1        | 16.5        | 6.7         | 4.1         | 2.3         | 1.7         | 1.3         | 0.7192        |

**Subgrade**

| SEC | STA | DF1<br>mils | DF2<br>mils | DF3<br>mils | DF4<br>mils | DF5<br>mils | DF6<br>mils | DF7<br>mils | BASIN<br>in^2 |
|-----|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 4   | 10  | 38.9        | 17.2        | 7.6         | 4.4         | 2.3         | 1.6         | 1.2         | 0.5270        |
| 4   | 15  | 43.6        | 15.9        | 6.7         | 4.4         | 2.4         | 1.7         | 1.3         | 0.5425        |
| 4   | 20  | 41.1        | 18.5        | 8.9         | 5.3         | 3.0         | 1.6         | 1.3         | 0.5751        |
| 4   | 25  | 48.7        | 18.7        | 7.5         | 4.1         | 2.3         | 1.7         | 1.3         | 0.5968        |
| 4   | 30  | 34.5        | 15.0        | 7.8         | 4.6         | 2.6         | 2.0         | 1.5         | 0.4945        |
| 4   | 35  | 36.6        | 13.9        | 6.9         | 4.3         | 2.4         | 1.7         | 1.4         | 0.4821        |
| 4   | 40  | 48.2        | 18.1        | 9.3         | 5.1         | 2.8         | 1.9         | 1.3         | 0.6200        |
| 4   | 45  | 53.2        | 21.9        | 9.7         | 5.6         | 2.9         | 2.0         | 1.5         | 0.6929        |
| 4   | 50  | 45.7        | 16.3        | 7.7         | 4.5         | 2.4         | 1.7         | 1.4         | 0.5658        |
| 4   | 55  | 43.5        | 18.9        | 8.7         | 4.4         | 2.3         | 1.7         | 1.3         | 0.5797        |
| 4   | 60  | 57.6        | 16.2        | 4.1         | 2.0         | 1.6         | 1.3         | 1.1         | 0.5751        |
| 4   | 65  | 49.0        | 12.6        | 7.0         | 4.4         | 2.2         | 1.7         | 1.3         | 0.5425        |
| 4   | 70  | 46.4        | 12.4        | 4.4         | 3.2         | 2.2         | 1.5         | 1.1         | 0.4976        |
| 4   | 75  | 50.5        | 19.7        | 7.5         | 4.0         | 2.0         | 1.4         | 1.1         | 0.6092        |
| 4   | 80  | 81.1        | 34.0        | 13.0        | 6.5         | 2.0         | 1.5         | 1.1         | 0.9781        |
| 4   | 85  | 83.1        | 19.2        | 5.6         | 3.5         | 2.0         | 1.8         | 1.1         | 0.7890        |
| 4   | 90  | 52.0        | 16.2        | 7.4         | 4.3         | 2.4         | 1.9         | 1.4         | 0.5999        |

| Subgrade |     | DF1  | DF2  | DF3  | DF4  | DF5  | DF6  | DF7  | BASIN  |
|----------|-----|------|------|------|------|------|------|------|--------|
| SEC      | STA | mils | mils | mils | mils | mils | mils | mils | in^2   |
| 5        | 10  | 44.5 | 16.8 | 8.2  | 4.6  | 2.4  | 1.7  | 1.5  | 0.5673 |
| 5        | 15  | 39.7 | 16.3 | 7.8  | 4.7  | 2.5  | 1.7  | 1.3  | 0.5332 |
| 5        | 20  | 43.7 | 17.3 | 8.6  | 4.7  | 2.0  | 1.4  | 1.3  | 0.5611 |
| 5        | 25  | 29.8 | 10.2 | 4.8  | 3.1  | 2.0  | 1.5  | 1.2  | 0.3782 |
| 5        | 30  | 36.1 | 13.3 | 6.3  | 4.0  | 2.5  | 1.9  | 1.4  | 0.4712 |
| 5        | 35  | 41.3 | 17.4 | 6.4  | 3.8  | 2.4  | 1.8  | 1.5  | 0.5363 |
| 5        | 40  | 52.0 | 21.5 | 10.2 | 5.1  | 2.6  | 2.0  | 1.3  | 0.6743 |
| 5        | 45  | 49.2 | 18.0 | 7.6  | 4.3  | 2.5  | 1.9  | 1.5  | 0.6030 |
| 5        | 50  | 50.9 | 15.3 | 6.3  | 3.6  | 2.3  | 1.8  | 1.3  | 0.5704 |
| 5        | 55  | 49.4 | 16.4 | 6.1  | 3.6  | 2.3  | 1.7  | 1.3  | 0.5689 |
| 5        | 60  | 62.7 | 17.5 | 6.7  | 3.9  | 2.2  | 1.6  | 1.3  | 0.6619 |
| 5        | 65  | 56.2 | 21.3 | 8.1  | 3.9  | 2.3  | 1.8  | 1.4  | 0.6696 |
| 5        | 70  | 67.1 | 24.1 | 9.8  | 5.4  | 2.6  | 1.9  | 1.5  | 0.7890 |
| 5        | 75  | 51.7 | 19.3 | 7.8  | 5.7  | 2.2  | 1.7  | 1.4  | 0.6371 |
| 5        | 80  | 94.1 | 16.1 | 7.6  | 4.6  | 2.5  | 1.9  | 1.5  | 0.8587 |
| 5        | 85  | 70.9 | 16.7 | 7.6  | 4.7  | 2.9  | 2.2  | 1.8  | 0.7363 |
| 5        | 90  | 66.6 | 15.2 | 8.3  | 5.5  | 3.4  | 2.5  | 1.8  | 0.7177 |

| Subgrade |     | DF1  | DF2  | DF3  | DF4  | DF5  | DF6  | DF7  | BASIN  |
|----------|-----|------|------|------|------|------|------|------|--------|
| SEC      | STA | mils | mils | mils | mils | mils | mils | mils | in^2   |
| 6        | 10  | 50.6 | 19.7 | 8.7  | 4.6  | 2.2  | 1.6  | 1.2  | 0.6278 |
| 6        | 15  | 46.4 | 15.4 | 6.4  | 3.5  | 1.9  | 1.5  | 1.1  | 0.5348 |
| 6        | 20  | 52.0 | 19.4 | 9.1  | 4.5  | 2.2  | 1.6  | 1.3  | 0.6340 |
| 6        | 25  | 52.4 | 16.1 | 7.1  | 4.1  | 2.2  | 1.7  | 1.3  | 0.5937 |
| 6        | 30  | 40.6 | 16.1 | 7.0  | 3.9  | 2.2  | 1.6  | 1.2  | 0.5193 |
| 6        | 35  | 38.4 | 16.9 | 7.6  | 4.2  | 2.2  | 1.7  | 1.3  | 0.5208 |
| 6        | 40  | 44.4 | 20.2 | 8.3  | 4.8  | 2.6  | 1.9  | 1.4  | 0.6045 |
| 6        | 45  | 42.3 | 17.2 | 8.6  | 5.2  | 2.7  | 2.0  | 1.6  | 0.5720 |
| 6        | 50  | 45.3 | 23.1 | 10.2 | 6.1  | 3.4  | 2.5  | 1.9  | 0.6774 |
| 6        | 55  | 55.0 | 24.7 | 10.0 | 5.3  | 2.7  | 2.0  | 1.5  | 0.7270 |
| 6        | 60  | 51.4 | 19.2 | 7.2  | 4.0  | 2.2  | 1.7  | 1.3  | 0.6154 |
| 6        | 65  | 41.0 | 17.2 | 7.7  | 4.2  | 2.2  | 1.7  | 1.3  | 0.5410 |
| 6        | 70  | 50.5 | 22.3 | 9.2  | 5.1  | 2.7  | 2.0  | 1.6  | 0.6696 |
| 6        | 75  | 52.7 | 19.1 | 6.7  | 4.2  | 2.5  | 2.0  | 1.5  | 0.6278 |
| 6        | 80  | 63.5 | 19.9 | 8.1  | 4.6  | 2.8  | 2.0  | 1.5  | 0.7161 |
| 6        | 85  | 60.6 | 16.5 | 8.3  | 4.9  | 2.6  | 1.9  | 1.5  | 0.6696 |
| 6        | 90  | 46.9 | 13.4 | 7.0  | 4.5  | 2.6  | 1.9  | 1.4  | 0.5472 |

**Subgrade**

| SEC | STA | DF1<br>mils | DF2<br>mils | DF3<br>mils | DF4<br>mils | DF5<br>mils | DF6<br>mils | DF7<br>mils | BASIN<br>in^2 |
|-----|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 7   | 10  | 41.2        | 15.9        | 8.1         | 5.0         | 2.6         | 1.9         | 1.5         | 0.5472        |
| 7   | 15  | 38.9        | 15.3        | 6.9         | 4.4         | 2.6         | 1.8         | 1.3         | 0.5131        |
| 7   | 20  | 33.4        | 14.3        | 6.9         | 4.0         | 2.2         | 1.7         | 1.4         | 0.4619        |
| 7   | 25  | 36.7        | 13.7        | 5.8         | 3.8         | 2.3         | 1.7         | 1.3         | 0.4697        |
| 7   | 30  | 43.5        | 17.2        | 7.8         | 4.1         | 2.1         | 1.7         | 1.3         | 0.5534        |
| 7   | 35  | 47.6        | 20.0        | 9.6         | 6.1         | 2.7         | 1.9         | 1.6         | 0.6417        |
| 7   | 40  | 41.7        | 18.3        | 8.9         | 5.4         | 2.8         | 2.0         | 1.5         | 0.5828        |
| 7   | 45  | 44.2        | 17.6        | 8.2         | 5.2         | 2.7         | 1.9         | 1.5         | 0.5828        |
| 7   | 50  | 47.6        | 16.2        | 7.5         | 4.4         | 2.6         | 2.0         | 1.5         | 0.5797        |
| 7   | 55  | 45.0        | 16.7        | 7.5         | 4.5         | 2.6         | 1.9         | 1.4         | 0.5673        |
| 7   | 60  | 41.3        | 15.6        | 7.2         | 4.5         | 2.4         | 1.7         | 1.3         | 0.5301        |
| 7   | 65  | 43.9        | 13.7        | 8.0         | 4.7         | 2.5         | 1.8         | 1.5         | 0.5379        |
| 7   | 70  | 42.8        | 18.1        | 9.1         | 5.6         | 3.1         | 2.2         | 1.5         | 0.5968        |
| 7   | 75  | 55.3        | 18.9        | 8.1         | 4.3         | 2.3         | 1.8         | 1.4         | 0.6479        |
| 7   | 80  | 50.6        | 19.5        | 8.7         | 5.0         | 2.6         | 1.9         | 1.5         | 0.6386        |
| 7   | 85  | 52.9        | 21.3        | 9.1         | 5.5         | 2.8         | 2.0         | 1.5         | 0.6789        |
| 7   | 90  | 51.2        | 20.0        | 8.6         | 4.7         | 2.5         | 1.9         | 1.4         | 0.6417        |

**Subgrade**

| SEC | STA | DF1<br>mils | DF2<br>mils | DF3<br>mils | DF4<br>mils | DF5<br>mils | DF6<br>mils | DF7<br>mils | BASIN<br>in^2 |
|-----|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 8   | 10  | 49.1        | 22.0        | 9.9         | 5.8         | 3.0         | 2.0         | 1.6         | 0.6743        |
| 8   | 15  | 46.0        | 16.9        | 8.1         | 4.8         | 2.4         | 1.7         | 1.3         | 0.5782        |
| 8   | 20  | 45.9        | 20.3        | 8.5         | 4.4         | 2.2         | 1.6         | 1.3         | 0.6014        |
| 8   | 25  | 38.7        | 17.4        | 7.7         | 4.3         | 2.7         | 1.8         | 1.4         | 0.5363        |
| 8   | 30  | 52.5        | 22.6        | 8.0         | 4.3         | 2.2         | 1.7         | 1.3         | 0.6588        |
| 8   | 35  | 57.4        | 24.2        | 10.6        | 5.0         | 2.2         | 1.7         | 1.2         | 0.7254        |
| 8   | 40  | 54.6        | 19.8        | 8.1         | 4.3         | 2.2         | 1.6         | 1.2         | 0.6464        |
| 8   | 45  | 47.6        | 16.4        | 7.8         | 4.4         | 2.4         | 1.9         | 1.4         | 0.5797        |
| 8   | 50  | 50.3        | 17.7        | 8.3         | 5.2         | 3.1         | 2.0         | 1.6         | 0.6293        |
| 8   | 55  | 55.3        | 20.6        | 9.1         | 5.1         | 3.0         | 2.0         | 1.7         | 0.6867        |
| 8   | 60  | 43.4        | 18.6        | 7.6         | 4.4         | 2.6         | 1.9         | 1.5         | 0.5766        |
| 8   | 65  | 56.6        | 24.3        | 9.7         | 5.2         | 2.6         | 1.9         | 1.5         | 0.7254        |
| 8   | 70  | 59.8        | 23.9        | 9.2         | 5.0         | 2.6         | 2.0         | 1.3         | 0.7378        |
| 8   | 75  | 53.5        | 19.4        | 7.2         | 3.4         | 2.0         | 1.7         | 1.3         | 0.6216        |
| 8   | 80  | 87.3        | 44.7        | 10.1        | 5.0         | 2.2         | 1.6         | 1.0         | 1.0835        |
| 8   | 85  | 97.8        | 36.5        | 13.5        | 5.4         | 2.4         | 1.8         | 1.3         | 1.1052        |
| 8   | 90  | 50.9        | 18.8        | 6.6         | 4.0         | 2.6         | 1.9         | 1.4         | 0.6138        |



| Subgrade |     | DF1  | DF2  | DF3  | DF4  | DF5  | DF6  | DF7  | BASIN  |
|----------|-----|------|------|------|------|------|------|------|--------|
| SEC      | STA | mils | mils | mils | mils | mils | mils | mils | in^2   |
| 9        | 10  | 55.2 | 18.9 | 7.6  | 4.3  | 2.3  | 1.8  | 1.4  | 0.6417 |
| 9        | 15  | 44.5 | 15.9 | 7.9  | 4.6  | 2.5  | 1.9  | 1.5  | 0.5611 |
| 9        | 20  | 42.4 | 18.0 | 8.6  | 5.4  | 2.8  | 2.0  | 1.5  | 0.5828 |
| 9        | 25  | 38.0 | 13.9 | 6.4  | 3.8  | 2.1  | 1.6  | 1.3  | 0.4790 |
| 9        | 30  | 34.4 | 15.1 | 6.3  | 3.5  | 2.0  | 1.5  | 1.2  | 0.4604 |
| 9        | 35  | 45.0 | 19.1 | 7.0  | 3.7  | 2.0  | 1.6  | 1.2  | 0.5689 |
| 9        | 40  | 43.5 | 14.5 | 7.3  | 4.7  | 2.6  | 1.9  | 1.5  | 0.5410 |
| 9        | 45  | 41.0 | 18.7 | 8.6  | 4.4  | 2.2  | 1.7  | 1.5  | 0.5627 |
| 9        | 50  | 47.6 | 19.9 | 7.5  | 4.0  | 2.2  | 1.7  | 1.3  | 0.5999 |
| 9        | 55  | 47.8 | 18.6 | 6.6  | 3.6  | 2.0  | 1.6  | 1.2  | 0.5766 |
| 9        | 60  | 61.5 | 16.9 | 6.6  | 3.5  | 1.9  | 1.6  | 1.2  | 0.6402 |
| 9        | 65  | 60.3 | 20.5 | 7.2  | 3.8  | 2.0  | 1.6  | 1.2  | 0.6743 |
| 9        | 70  | 47.5 | 18.8 | 7.3  | 3.9  | 2.0  | 1.5  | 1.3  | 0.5844 |
| 9        | 75  | 48.2 | 16.3 | 5.0  | 3.2  | 2.2  | 1.7  | 1.3  | 0.5503 |
| 9        | 80  | 49.8 | 18.0 | 7.9  | 5.0  | 2.9  | 2.1  | 1.6  | 0.6216 |
| 9        | 85  | 49.2 | 19.3 | 8.0  | 4.4  | 2.3  | 1.8  | 1.3  | 0.6138 |
| 9        | 90  | 52.1 | 18.0 | 8.2  | 4.6  | 2.4  | 1.8  | 1.3  | 0.6247 |

| Subgrade |     | DF1  | DF2  | DF3  | DF4  | DF5  | DF6  | DF7  | BASIN  |
|----------|-----|------|------|------|------|------|------|------|--------|
| SEC      | STA | mils | mils | mils | mils | mils | mils | mils | in^2   |
| 10       | 10  | 62.0 | 19.1 | 8.5  | 5.5  | 2.7  | 2.0  | 1.5  | 0.7099 |
| 10       | 15  | 51.7 | 13.7 | 6.7  | 4.4  | 2.5  | 1.9  | 1.4  | 0.5735 |
| 10       | 20  | 52.7 | 19.3 | 7.8  | 4.4  | 2.2  | 1.6  | 1.2  | 0.6293 |
| 10       | 25  | 55.2 | 17.4 | 5.6  | 3.5  | 1.9  | 1.5  | 1.1  | 0.5999 |
| 10       | 30  | 55.2 | 18.3 | 7.2  | 4.1  | 2.3  | 1.8  | 1.3  | 0.6324 |
| 10       | 35  | 49.0 | 16.2 | 6.9  | 4.4  | 2.3  | 1.7  | 1.2  | 0.5766 |
| 10       | 40  | 52.4 | 14.5 | 5.8  | 3.7  | 2.2  | 1.6  | 1.2  | 0.5673 |
| 10       | 45  | 50.9 | 17.2 | 7.2  | 4.3  | 2.3  | 1.7  | 1.3  | 0.5968 |
| 10       | 50  | 46.0 | 14.8 | 5.6  | 3.5  | 2.0  | 1.6  | 1.5  | 0.5270 |
| 10       | 55  | 52.9 | 17.6 | 7.0  | 4.3  | 2.5  | 1.8  | 1.3  | 0.6154 |
| 10       | 60  | 47.2 | 15.4 | 7.4  | 4.7  | 2.4  | 1.8  | 1.4  | 0.5689 |
| 10       | 65  | 46.7 | 14.1 | 7.1  | 4.1  | 2.4  | 1.8  | 1.3  | 0.5456 |
| 10       | 70  | 64.6 | 14.4 | 5.9  | 4.0  | 2.4  | 1.9  | 1.4  | 0.6479 |
| 10       | 75  | 47.7 | 11.7 | 5.5  | 3.5  | 2.1  | 1.6  | 1.2  | 0.5084 |
| 10       | 80  | 51.2 | 13.4 | 5.7  | 3.4  | 1.8  | 1.5  | 1.3  | 0.5394 |
| 10       | 85  | 57.0 | 16.7 | 7.2  | 4.1  | 2.0  | 1.5  | 1.2  | 0.6216 |
| 10       | 90  | 53.3 | 16.3 | 7.2  | 4.1  | 2.1  | 1.6  | 1.2  | 0.5983 |

**APPENDIX C: BACK-CALCULATED SUBGRADE MODULUS.**

| TEST<br>SECTION | ELASTIC MODULUS (psi) |       |       |
|-----------------|-----------------------|-------|-------|
|                 | LOCATION              | FWD   | CLEGG |
| 1               | 10                    | 13757 | 13158 |
| 1               | 15                    | 15742 | 14660 |
| 1               | 20                    | 15388 | 17909 |
| 1               | 25                    | 15905 | 13899 |
| 1               | 30                    | 18648 | 9137  |
| 1               | 35                    | 17916 | 13158 |
| 1               | 40                    | 21179 | 13158 |
| 1               | 45                    | 16931 | 16244 |
| 1               | 50                    | 13113 | 12437 |
| 1               | 55                    | 12813 | 11736 |
| 1               | 60                    | 15105 | 21483 |
| 1               | 65                    | 13696 | 15442 |
| 1               | 70                    | 10976 | 15442 |
| 1               | 75                    | 10323 | 18772 |
| 1               | 80                    | 11135 | 15442 |
| 1               | 85                    | 9063  | 15442 |
| 1               | 90                    | 9017  | 14660 |
| 2               | 10                    | 17509 | 15442 |
| 2               | 15                    | 19081 | 15442 |
| 2               | 20                    | 16050 | 16244 |
| 2               | 25                    | 20141 | 5848  |
| 2               | 30                    | 19534 | 15442 |
| 2               | 35                    | 14433 | 17066 |
| 2               | 40                    | 12277 | 13158 |
| 2               | 50                    | 10918 | 9137  |
| 2               | 55                    | 10908 | 11736 |
| 2               | 60                    | 7906  | 9137  |
| 2               | 65                    | 9117  | 10396 |
| 2               | 70                    | 13575 | 15442 |
| 2               | 75                    | 13383 | 11056 |
| 2               | 80                    | 10562 | 17066 |
| 2               | 85                    | 7158  | 13158 |
| 2               | 90                    | 6666  | 4914  |
| 3               | 10                    | 14604 | 14660 |
| 3               | 15                    | 14727 | 14660 |
| 3               | 20                    | 13696 | 13158 |

| TEST<br>SECTION | ELASTIC MODULUS (psi) |       |       |
|-----------------|-----------------------|-------|-------|
|                 | LOCATION              | FWD   | CLEGG |
| 3               | 25                    | 17143 | 13158 |
| 3               | 30                    | 19350 | 16244 |
| 3               | 35                    | 15884 | 12437 |
| 3               | 40                    | 14727 | 11736 |
| 3               | 45                    | 15014 | 13158 |
| 3               | 50                    | 13071 | 20559 |
| 3               | 60                    | 6810  | 14660 |
| 3               | 65                    | 10021 | 16244 |
| 3               | 70                    | 8811  | 13899 |
| 3               | 75                    | 8125  | 4914  |
| 3               | 80                    | 9303  | 9137  |
| 3               | 85                    | 7298  | 7401  |
| 3               | 90                    | 6641  | 2284  |
| 4               | 10                    | 12463 | 9756  |
| 4               | 15                    | 11135 | 3665  |
| 4               | 20                    | 11818 | 7401  |
| 4               | 25                    | 9965  | 6345  |
| 4               | 35                    | 13268 | 6345  |
| 4               | 40                    | 10062 | 7401  |
| 4               | 45                    | 9124  | 6345  |
| 4               | 50                    | 10608 | 7959  |
| 4               | 55                    | 11145 | 15442 |
| 4               | 60                    | 8425  | 6345  |
| 4               | 65                    | 9908  | 7959  |
| 4               | 70                    | 10455 | 4061  |
| 5               | 10                    | 10908 | 7959  |
| 5               | 15                    | 12228 | 11736 |
| 5               | 20                    | 11105 | 7959  |
| 5               | 25                    | 16283 | 13899 |
| 5               | 30                    | 13442 | 4914  |
| 5               | 35                    | 11750 | 5370  |
| 5               | 40                    | 9338  | 5370  |
| 5               | 45                    | 9869  | 6863  |
| 5               | 50                    | 9540  | 6863  |
| 5               | 55                    | 9829  | 6345  |
| 5               | 60                    | 7738  | 4061  |

| TEST<br>SECTION | ELASTIC MODULUS (psi) |       |       |
|-----------------|-----------------------|-------|-------|
|                 | LOCATION              | FWD   | CLEGG |
| 5               | 65                    | 8638  | 8538  |
| 5               | 70                    | 7234  | 4477  |
| 5               | 75                    | 9395  | 4914  |
| 5               | 80                    | 5157  | 4061  |
| 5               | 85                    | 6840  | 2599  |
| 5               | 90                    | 7289  | 4061  |
| 6               | 10                    | 9585  | 4477  |
| 6               | 15                    | 10455 | 6345  |
| 6               | 20                    | 9338  | 4061  |
| 6               | 25                    | 9268  | 5370  |
| 6               | 30                    | 11955 | 14660 |
| 6               | 35                    | 12629 | 8538  |
| 6               | 40                    | 10937 | 9137  |
| 6               | 45                    | 11477 | 9756  |
| 6               | 50                    | 10718 | 9137  |
| 6               | 55                    | 8830  | 5370  |
| 6               | 60                    | 9438  | 9137  |
| 6               | 65                    | 11841 | 9137  |
| 6               | 70                    | 9607  | 10396 |
| 6               | 75                    | 9212  | 5370  |
| 6               | 80                    | 7642  | 2284  |
| 6               | 85                    | 8014  | 5848  |
| 6               | 90                    | 10341 | 4061  |
| 7               | 10                    | 11773 | 12437 |
| 7               | 15                    | 12476 | 13158 |
| 7               | 20                    | 14535 | 13158 |
| 7               | 25                    | 13225 | 15442 |
| 7               | 30                    | 11165 | 5848  |
| 7               | 35                    | 10204 | 13158 |
| 7               | 40                    | 11639 | 9756  |
| 7               | 45                    | 10976 | 9756  |
| 7               | 50                    | 10195 | 9137  |
| 7               | 55                    | 10784 | 9137  |
| 7               | 60                    | 11762 | 11736 |
| 7               | 65                    | 11065 | 13158 |
| 7               | 70                    | 11329 | 9756  |

| TEST<br>SECTION | ELASTIC MODULUS (psi) |       |       |
|-----------------|-----------------------|-------|-------|
|                 | LOCATION              | FWD   | CLEGG |
| 7               | 75                    | 8779  | 10396 |
| 7               | 80                    | 9585  | 6863  |
| 7               | 85                    | 9171  | 9137  |
| 7               | 90                    | 9482  | 7959  |
| 8               | 10                    | 9877  | 2934  |
| 8               | 15                    | 10544 | 7959  |
| 8               | 20                    | 10571 | 12437 |
| 8               | 25                    | 12539 | 16244 |
| 8               | 30                    | 9240  | 4477  |
| 8               | 35                    | 8454  | 4477  |
| 8               | 40                    | 8880  | 2284  |
| 8               | 45                    | 10204 | 5848  |
| 8               | 50                    | 9645  | 6863  |
| 8               | 55                    | 8773  | 5370  |
| 8               | 60                    | 11175 | 5848  |
| 8               | 65                    | 8578  | 7959  |
| 8               | 70                    | 8115  | 6863  |
| 8               | 75                    | 9070  | 4061  |
| 8               | 80                    | 5557  | 3665  |
| 8               | 85                    | 4960  | 4914  |
| 8               | 90                    | 9526  | 4477  |
| 9               | 10                    | 8792  | 6345  |
| 9               | 15                    | 10898 | 9137  |
| 9               | 20                    | 11434 | 13158 |
| 9               | 25                    | 12760 | 13158 |
| 9               | 30                    | 14119 | 11736 |
| 9               | 35                    | 10775 | 4061  |
| 9               | 40                    | 11165 | 5370  |
| 9               | 45                    | 11829 | 15442 |
| 9               | 50                    | 10204 | 4477  |
| 9               | 55                    | 10145 | 7959  |
| 9               | 60                    | 7896  | 4914  |
| 9               | 65                    | 8046  | 4477  |
| 9               | 70                    | 10212 | 6345  |
| 9               | 75                    | 10062 | 6863  |
| 9               | 80                    | 9752  | 8538  |

| TEST<br>SECTION | ELASTIC MODULUS (psi) |       |       |
|-----------------|-----------------------|-------|-------|
|                 | LOCATION              | FWD   | CLEGG |
| 9               | 85                    | 9869  | 5370  |
| 9               | 90                    | 9310  | 5848  |
| 10              | 10                    | 7821  | 3289  |
| 10              | 15                    | 9395  | 3289  |
| 10              | 20                    | 9212  | 6345  |
| 10              | 25                    | 8798  | 4061  |
| 10              | 30                    | 8798  | 6863  |
| 10              | 35                    | 9900  | 4061  |
| 10              | 40                    | 9254  | 2934  |
| 10              | 45                    | 9540  | 4061  |
| 10              | 50                    | 10544 | 5370  |
| 10              | 55                    | 9178  | 3665  |
| 10              | 60                    | 10280 | 4477  |
| 10              | 65                    | 10402 | 4914  |
| 10              | 70                    | 7516  | 2934  |
| 10              | 75                    | 10170 | 3665  |
| 10              | 80                    | 9482  | 4914  |
| 10              | 85                    | 8507  | 3665  |
| 10              | 90                    | 9110  | 4914  |

APPENDIX D: FIELD CBR DATA FROM CLEGG HAMMER AND IN-SITU CBR TESTING.

| Test Section | Location | Subgrade Clegg (CIV) | Base Clegg (CIV) | Subgrade Clegg (CBR) | Base Clegg (CBR) | Subgrade CBR (CBR) | Base CBR (CBR) | Subgrade DCP (CBR) | Base DCP (CBR) |
|--------------|----------|----------------------|------------------|----------------------|------------------|--------------------|----------------|--------------------|----------------|
| 1            | 10       | 36                   | 16               | 91                   | 18               |                    |                | 38                 | 20             |
| 1            | 15       | 38                   | 25               | 101                  | 44               |                    |                |                    | 17             |
| 1            | 20       | 42                   | 8                | 123                  | 4                | 25                 |                | 33                 | 17             |
| 1            | 25       | 37                   | 37               | 96                   | 96               |                    | 7              |                    | 15             |
| 1            | 30       | 30                   |                  | 63                   |                  |                    |                | 32                 | 17             |
| 1            | 35       | 36                   |                  | 91                   |                  |                    |                |                    | 12             |
| 1            | 40       | 36                   |                  | 91                   |                  |                    |                | 19                 | 22             |
| 1            | 45       | 40                   |                  | 112                  |                  |                    |                |                    | 19             |
| 1            | 50       | 35                   |                  | 86                   |                  | 39                 | 9              | 29                 | 14             |
| 1            | 55       | 34                   |                  | 81                   |                  |                    |                |                    | 13             |
| 1            | 60       | 46                   |                  | 148                  |                  |                    |                | 23                 | 15             |
| 1            | 65       | 39                   |                  | 106                  |                  |                    |                |                    | 17             |
| 1            | 70       | 39                   |                  | 106                  |                  |                    |                | 24                 | 14             |
| 1            | 75       | 43                   |                  | 129                  |                  |                    | 8              |                    | 16             |
| 1            | 80       | 39                   |                  | 106                  |                  | 32                 |                | 26                 | 16             |
| 1            | 85       | 39                   |                  | 106                  |                  |                    |                |                    | 11             |
| 1            | 90       | 38                   |                  | 101                  |                  |                    |                | 32                 | 14             |
| 2            | 10       | 39                   |                  | 106                  |                  |                    |                | 28                 | 31             |
| 2            | 15       | 39                   |                  | 106                  |                  |                    |                |                    | 31             |
| 2            | 20       | 40                   |                  | 112                  |                  | 20                 |                | 25                 | 30             |
| 2            | 25       | 24                   |                  | 40                   |                  |                    | 24             |                    | 33             |
| 2            | 30       | 39                   |                  | 106                  |                  |                    |                | 36                 | 29             |
| 2            | 35       | 41                   |                  | 118                  |                  |                    |                |                    | 26             |
| 2            | 40       | 36                   |                  | 91                   |                  |                    |                | 22                 | 28             |
| 2            | 45       | 35                   |                  | 86                   |                  |                    |                |                    | 26             |
| 2            | 50       | 30                   |                  | 63                   |                  | 21                 | 39             | 24                 | 27             |
| 2            | 55       | 34                   |                  | 81                   |                  |                    |                |                    | 25             |
| 2            | 60       | 30                   |                  | 63                   |                  |                    |                | 16                 | 25             |
| 2            | 65       | 32                   |                  | 72                   |                  |                    |                |                    | 31             |
| 2            | 70       | 39                   |                  | 106                  |                  |                    |                | 27                 | 26             |
| 2            | 75       | 33                   |                  | 76                   |                  |                    | 32             |                    | 28             |
| 2            | 80       | 41                   |                  | 118                  |                  | 27                 |                | 24                 | 29             |
| 2            | 85       | 36                   |                  | 91                   |                  |                    |                |                    | 34             |
| 2            | 90       | 22                   |                  | 34                   |                  |                    |                | 21                 | 39             |

| Test Section | Location | Subgrade Clegg (CIV) | Base Clegg (CIV) | Subgrade Clegg (CBR) | Base Clegg (CBR) | Subgrade CBR (CBR) | Base CBR (CBR) | Subgrade DCP (CBR) | Base DCP (CBR) |
|--------------|----------|----------------------|------------------|----------------------|------------------|--------------------|----------------|--------------------|----------------|
| 3            | 10       | 38                   | 24               | 101                  | 40               |                    |                | 19                 |                |
| 3            | 15       | 38                   | 28               | 101                  | 55               |                    |                |                    |                |
| 3            | 20       | 36                   | 29               | 91                   | 59               |                    |                | 42                 |                |
| 3            | 25       | 36                   | 27               | 91                   | 51               |                    | 19             |                    |                |
| 3            | 30       | 40                   | 29               | 112                  | 59               |                    |                | 29                 |                |
| 3            | 35       | 35                   | 29               | 86                   | 59               |                    |                |                    |                |
| 3            | 40       | 34                   | 27               | 81                   | 51               |                    |                | 32                 |                |
| 3            | 45       | 36                   | 26               | 91                   | 47               |                    |                |                    |                |
| 3            | 50       | 45                   | 26               | 142                  | 47               | 29                 | 28             | 38                 |                |
| 3            | 55       | 56                   | 24               | 220                  | 40               |                    |                |                    |                |
| 3            | 60       | 38                   | 25               | 101                  | 44               |                    |                | 19                 |                |
| 3            | 65       | 40                   | 20               | 112                  | 28               |                    |                |                    |                |
| 3            | 70       | 37                   | 27               | 96                   | 51               |                    |                | 31                 |                |
| 3            | 75       | 22                   | 19               | 34                   | 25               |                    | 18             |                    |                |
| 3            | 80       | 30                   | 25               | 63                   | 44               | 44                 |                | 11                 |                |
| 3            | 85       | 27                   | 26               | 51                   | 47               |                    |                |                    |                |
| 3            | 90       | 15                   | 24               | 16                   | 40               |                    |                | 10                 |                |
| 4            | 10       | 31                   | 29               | 67                   | 59               |                    |                | 25                 |                |
| 4            | 15       | 19                   | 32               | 25                   | 72               |                    |                |                    |                |
| 4            | 20       | 27                   | 32               | 51                   | 72               | 32                 |                | 30                 |                |
| 4            | 25       | 25                   | 32               | 44                   | 72               |                    | 33             |                    |                |
| 4            | 30       | 3                    | 30               | 1                    | 63               |                    |                | 28                 |                |
| 4            | 35       | 25                   | 28               | 44                   | 55               |                    |                |                    |                |
| 4            | 40       | 27                   | 30               | 51                   | 63               |                    |                | 32                 |                |
| 4            | 45       | 25                   | 34               | 44                   | 81               |                    |                |                    |                |
| 4            | 50       | 28                   | 33               | 55                   | 76               | 32                 | 40             | 33                 |                |
| 4            | 55       | 39                   | 37               | 106                  | 96               |                    |                |                    |                |
| 4            | 60       | 25                   | 61               | 44                   | 260              |                    |                | 12                 |                |
| 4            | 65       | 28                   | 64               | 55                   | 287              |                    |                |                    |                |
| 4            | 70       | 20                   | 30               | 28                   | 63               |                    |                | 13                 |                |
| 4            | 75       | 75                   | 34               | 394                  | 81               |                    | 25             |                    |                |
| 4            | 80       | 80                   | 29               | 448                  | 59               | 29                 |                | 11                 |                |
| 4            | 85       | 85                   | 31               | 506                  | 67               |                    |                |                    |                |
| 4            | 90       | 90                   | 25               | 567                  | 44               |                    |                | 13                 |                |



| Test Section | Location | Subgrade Clegg (CIV) | Base Clegg (CIV) | Subgrade Clegg (CBR) | Base Clegg (CBR) | Subgrade CBR (CBR) | Base CBR (CBR) | Subgrade DCP (CBR) | Base DCP (CBR) |
|--------------|----------|----------------------|------------------|----------------------|------------------|--------------------|----------------|--------------------|----------------|
| 5            | 10       | 28                   | 29               | 55                   | 59               |                    |                | 15                 | 55             |
| 5            | 15       | 34                   | 35               | 81                   | 86               |                    |                |                    | 57             |
| 5            | 20       | 28                   | 86               | 55                   | 518              | 25                 |                | 21                 | 61             |
| 5            | 25       | 37                   | 25               | 96                   | 44               |                    | 12             |                    | 59             |
| 5            | 30       | 22                   | 37               | 34                   | 96               |                    |                | 23                 | 54             |
| 5            | 35       | 23                   | 40               | 37                   | 112              |                    |                |                    | 60             |
| 5            | 40       | 23                   | 43               | 37                   | 129              |                    |                | 21                 | 54             |
| 5            | 45       | 26                   | 41               | 47                   | 118              |                    |                |                    | 56             |
| 5            | 50       | 26                   | 46               | 47                   | 148              | 17                 | 36             | 22                 | 54             |
| 5            | 55       | 25                   | 47               | 44                   | 155              |                    |                |                    | 65             |
| 5            | 60       | 20                   | 57               | 28                   | 227              |                    |                | 12                 | 66             |
| 5            | 65       | 29                   | 52               | 59                   | 189              |                    |                |                    | 56             |
| 5            | 70       | 21                   | 41               | 31                   | 118              |                    |                | 23                 | 60             |
| 5            | 75       | 22                   | 40               | 34                   | 112              |                    | 23             |                    | 51             |
| 5            | 80       | 20                   | 35               | 28                   | 86               | 14                 |                | 11                 | 64             |
| 5            | 85       | 16                   | 43               | 18                   | 129              |                    |                |                    | 62             |
| 5            | 90       | 20                   | 39               | 28                   | 106              |                    |                | 8                  | 89             |
| 6            | 10       | 21                   | 54               | 31                   | 204              |                    |                | 17                 | 92             |
| 6            | 15       | 25                   | 53               | 44                   | 197              |                    |                |                    | 85             |
| 6            | 20       | 20                   | 50               | 28                   | 175              | 17                 |                | 15                 | 73             |
| 6            | 25       | 23                   | 34               | 37                   | 81               |                    | 40             |                    | 81             |
| 6            | 30       | 38                   | 55               | 101                  | 212              |                    |                | 18                 | 77             |
| 6            | 35       | 29                   | 47               | 59                   | 155              |                    |                |                    | 63             |
| 6            | 40       | 30                   | 42               | 63                   | 123              |                    |                | 21                 | 63             |
| 6            | 45       | 31                   | 47               | 67                   | 155              |                    |                |                    | 66             |
| 6            | 50       | 30                   | 52               | 63                   | 189              | 28                 | 50             | 19                 | 74             |
| 6            | 55       | 23                   | 54               | 37                   | 204              |                    |                |                    | 74             |
| 6            | 60       | 30                   | 50               | 63                   | 175              |                    |                | 17                 | 62             |
| 6            | 65       | 30                   | 45               | 63                   | 142              |                    |                |                    | 65             |
| 6            | 70       | 32                   | 41               | 72                   | 118              |                    |                | 22                 | 69             |
| 6            | 75       | 23                   | 37               | 37                   | 96               |                    | 46             |                    | 81             |
| 6            | 80       | 15                   | 51               | 16                   | 182              | 8                  |                | 10                 | 61             |
| 6            | 85       | 24                   | 53               | 40                   | 197              |                    |                |                    | 119            |
| 6            | 90       | 20                   | 44               | 28                   | 136              |                    |                | 13                 | 88             |

| Test Section | Location | Subgrade Clegg (CIV) | Base Clegg (CIV) | Subgrade Clegg (CBR) | Base Clegg (CBR) | Subgrade CBR (CBR) | Base CBR (CBR) | Subgrade DCP (CBR) | Base DCP (CBR) |
|--------------|----------|----------------------|------------------|----------------------|------------------|--------------------|----------------|--------------------|----------------|
| 7            | 10       | 35                   | 76               | 86                   | 404              |                    |                | 13                 | 146            |
| 7            | 15       | 36                   | 52               | 91                   | 189              |                    |                |                    | 78             |
| 7            | 20       | 36                   | 49               | 91                   | 168              | 38                 |                | 29                 | 71             |
| 7            | 25       | 39                   | 68               | 106                  | 324              |                    | 25             |                    | 76             |
| 7            | 30       | 24                   | 56               | 40                   | 220              |                    |                | 14                 | 80             |
| 7            | 35       | 36                   | 66               | 91                   | 305              |                    |                |                    | 85             |
| 7            | 40       | 31                   | 73               | 67                   | 373              |                    |                | 19                 | 77             |
| 7            | 45       | 31                   | 66               | 67                   | 305              |                    |                |                    | 64             |
| 7            | 50       | 30                   | 68               | 63                   | 324              | 34                 | 32             | 17                 |                |
| 7            | 55       | 30                   | 69               | 63                   | 333              |                    |                |                    |                |
| 7            | 60       | 34                   | 68               | 81                   | 324              |                    |                | 18                 |                |
| 7            | 65       | 36                   | 94               | 91                   | 619              |                    |                |                    |                |
| 7            | 70       | 31                   | 67               | 67                   | 314              |                    |                | 11                 |                |
| 7            | 75       | 32                   | 73               | 72                   | 373              |                    | 53             |                    |                |
| 7            | 80       | 26                   | 77               | 47                   | 415              | 36                 |                | 16                 |                |
| 7            | 85       | 30                   | 72               | 63                   | 363              |                    |                |                    |                |
| 7            | 90       | 28                   | 70               | 55                   | 343              |                    |                | 11                 |                |
| 8            | 10       | 17                   | 38               | 20                   | 101              |                    |                | 17                 | 119            |
| 8            | 15       | 28                   | 42               | 55                   | 123              |                    |                |                    | 111            |
| 8            | 20       | 35                   | 42               | 86                   | 123              | 17                 |                | 14                 | 92             |
| 8            | 25       | 40                   | 52               | 112                  | 189              |                    | 49             |                    | 83             |
| 8            | 30       | 21                   | 47               | 31                   | 155              |                    |                | 26                 | 71             |
| 8            | 35       | 21                   | 42               | 31                   | 123              |                    |                |                    | 67             |
| 8            | 40       | 15                   | 37               | 16                   | 96               |                    |                | 11                 | 75             |
| 8            | 45       | 24                   | 35               | 40                   | 86               |                    |                |                    | 115            |
| 8            | 50       | 26                   | 41               | 47                   | 118              | 23                 | 36             | 26                 | 67             |
| 8            | 55       | 23                   | 56               | 37                   | 220              |                    |                |                    | 86             |
| 8            | 60       | 24                   | 32               | 40                   | 72               |                    |                | 12                 | 60             |
| 8            | 65       | 28                   | 41               | 55                   | 118              |                    |                |                    | 91             |
| 8            | 70       | 26                   | 45               | 47                   | 142              |                    |                | 15                 | 81             |
| 8            | 75       | 20                   | 38               | 28                   | 101              |                    | 41             |                    | 67             |
| 8            | 80       | 19                   |                  | 25                   |                  | 16                 |                | 10                 | 60             |
| 8            | 85       | 22                   |                  | 34                   |                  |                    |                |                    | 73             |
| 8            | 90       | 21                   |                  | 31                   |                  |                    |                | 9                  | 44             |

| Test Section | Location | Subgrade Clegg (CIV) | Base Clegg (CIV) | Subgrade Clegg (CBR) | Base Clegg (CBR) | Subgrade CBR (CBR) | Base CBR (CBR) | Subgrade DCP (CBR) | Base DCP (CBR) |
|--------------|----------|----------------------|------------------|----------------------|------------------|--------------------|----------------|--------------------|----------------|
| 9            | 10       | 25                   |                  | 44                   |                  |                    |                | 13                 |                |
| 9            | 15       | 30                   |                  | 63                   |                  |                    |                |                    |                |
| 9            | 20       | 36                   |                  | 91                   |                  | 44                 |                | 15                 |                |
| 9            | 25       | 36                   |                  | 91                   |                  |                    |                |                    |                |
| 9            | 30       | 34                   |                  | 81                   |                  |                    |                | 22                 |                |
| 9            | 35       | 20                   |                  | 28                   |                  |                    |                |                    |                |
| 9            | 40       | 23                   |                  | 37                   |                  |                    |                | 17                 |                |
| 9            | 45       | 39                   |                  | 106                  |                  |                    |                |                    |                |
| 9            | 50       | 21                   |                  | 31                   |                  | 37                 |                | 16                 |                |
| 9            | 55       | 28                   |                  | 55                   |                  |                    |                |                    |                |
| 9            | 60       | 22                   |                  | 34                   |                  |                    |                | 10                 |                |
| 9            | 65       | 21                   |                  | 31                   |                  |                    |                |                    |                |
| 9            | 70       | 25                   |                  | 44                   |                  |                    |                | 12                 |                |
| 9            | 75       | 26                   |                  | 47                   |                  |                    |                |                    |                |
| 9            | 80       | 29                   |                  | 59                   |                  | 28                 |                | 14                 |                |
| 9            | 85       | 23                   |                  | 37                   |                  |                    |                |                    |                |
| 9            | 90       | 24                   |                  | 40                   |                  |                    |                | 18                 |                |
| 10           | 10       | 18                   |                  | 23                   |                  |                    |                | 16                 |                |
| 10           | 15       | 18                   |                  | 23                   |                  |                    |                |                    |                |
| 10           | 20       | 25                   |                  | 44                   |                  | 19                 |                | 9                  |                |
| 10           | 25       | 20                   |                  | 28                   |                  |                    | 49             |                    |                |
| 10           | 30       | 26                   |                  | 47                   |                  |                    |                | 16                 |                |
| 10           | 35       | 20                   |                  | 28                   |                  |                    |                |                    |                |
| 10           | 40       | 17                   |                  | 20                   |                  |                    |                | 17                 |                |
| 10           | 45       | 20                   |                  | 28                   |                  |                    |                |                    |                |
| 10           | 50       | 23                   |                  | 37                   |                  | 23                 | 28             | 12                 | 145            |
| 10           | 55       | 19                   |                  | 25                   |                  |                    |                |                    |                |
| 10           | 60       | 21                   |                  | 31                   |                  |                    |                | 18                 |                |
| 10           | 65       | 22                   |                  | 34                   |                  |                    |                |                    |                |
| 10           | 70       | 17                   |                  | 20                   |                  |                    |                | 10                 |                |
| 10           | 75       | 19                   |                  | 25                   |                  |                    | 23             |                    |                |
| 10           | 80       | 22                   |                  | 34                   |                  | 32                 |                | 10                 |                |
| 10           | 85       | 19                   |                  | 25                   |                  |                    |                |                    |                |
| 10           | 90       | 22                   |                  | 34                   |                  |                    |                | 12                 | 119            |

# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestion for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

|  |   |  |                                      |
|--|---|--|--------------------------------------|
| 1. AGENCY USE ONLY (Leave blank)   | 2. REPORT DATE<br>September 1994                            | 3. REPORT TYPE AND DATES COVERED   |                                      |
| 4. TITLE AND SUBTITLE<br><br>Layer Coefficients for NHDOT Pavement Materials   |   | 5. FUNDING NUMBERS   |                                      |
| 6. AUTHORS<br><br>Vincent C. Janoo   |   |  |                                      |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br><br>U.S. Army Cold Regions Research and Engineering Laboratory<br>72 Lyme Road<br>Hanover, New Hampshire 03755-1290  |   | 8. PERFORMING ORGANIZATION<br>REPORT NUMBER<br><br>Special Report 94-30  |                                      |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)<br><br>New Hampshire Department<br>of Transportation<br>Concord, New Hampshire   |   | 10. SPONSORING/MONITORING<br>AGENCY REPORT NUMBER<br><br>U.S. Department of Transportation<br>Federal Highway Administration<br>Washington, D.C. |                                      |
| 11. SUPPLEMENTARY NOTES  |   |  |                                      |
| 12a. DISTRIBUTION/AVAILABILITY STATEMENT<br><br>Approved for public release; distribution is unlimited.<br><br>Available from NTIS, Springfield, Virginia 22161  |   | 12b. DISTRIBUTION CODE   |                                      |
| 13. ABSTRACT (Maximum 200 words)<br><br>In 1992, the New Hampshire Department of Transportation (NHDOT) experimented with the use of reclaimed asphalt concrete as a base course material, identified by NHDOT as reclaimed stabilized base (RSB). The RSB and a control test section were placed on Interstate 93 between exits 18 and 19. The RSB test section was designed to the same structural number (SN) as the control. To evaluate the structural capacity of these test sections, the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) conducted deflection tests using a Dynatest 8000 falling weight deflectometer (FWD). Preliminary analysis of the results by NHDOT personnel showed higher deflections in the reclaimed asphalt concrete test sections. The explanation was that the layer coefficient used for the RSB layer in the design was probably incorrect. A total of 10 test sections constituting the base course materials used by NHDOT were built near Bow, New Hampshire. CRREL evaluated and estimated the layer coefficients of the base course materials. The test program was developed to characterize the material in more than one way. Tests were conducted with the heavy weight deflectometer (HWD), dynamic cone penetrometer (DCP) and the Clegg hammer. In-situ California bearing ratio (CBR) tests were also conducted. The deflections from the HWD were used with the WESDEF back-calculation program to determine the layer moduli. The moduli were then used with the AASHTO Design Guide to calculate the layer coefficients. The layer coefficients were also determined with the method proposed by Rohde. The CBR values from the Clegg hammer, in-situ CBR and DCP tests were also used in the relationships in the HDM model to determine the layer coefficients. |   |  |                                      |
| 14. SUBJECT TERMS<br>Back-calculation<br>California bearing ratio<br>Clegg hammer<br>Dynamic cone penetrometer<br>Falling weight deflectometer<br>Layer moduli<br>Reclaimed asphalt concrete   |   |  | 15. NUMBER OF PAGES<br>53            |
|  |   |  | 16. PRICE CODE                       |
| 17. SECURITY CLASSIFICATION<br>OF REPORT<br>UNCLASSIFIED   | 18. SECURITY CLASSIFICATION<br>OF THIS PAGE<br>UNCLASSIFIED | 19. SECURITY CLASSIFICATION<br>OF ABSTRACT<br>UNCLASSIFIED   | 20. LIMITATION OF ABSTRACT<br><br>UL |